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A DICTIONARY OF DAIRYING

A DICTIONARY OF DAIRYING

BY

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WITH SOME SECTIONS SPECIALLY CONTRIBUTED

SECOND EDITION

Revised and Enlarged

LONDON
LEONARD HILL [BOOKS] LTD.
1963

Leonard Hill [Books] Ltd.
The Tower, 229-243 Shepherds Bush Road, Hammersmith,
London, W.6.

First published	1950
Second edition	1955
Reprinted	1963

PRINTED IN GREAT BRITAIN AT
THE UNIVERSITY PRESS
ABERDEEN

TO

PROF. H. D. KAY

DR. A. T. R. MATTICK

AND MY FORMER COLLEAGUES

AT THE N.I.R.D.

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CODE USED FOR BOOKS

Code	Book
Adam	*The Physics and Chemistry of Surfaces* (1941)
AOAC	*Methods of Analysis of the Association of Official Agricultural Chemists* (1950)
Bacharach	*Science and Nutrition* (1947), London
Bacharach and Rendle	*The Nation's Food* (1947), London
Badger and McCabe	*Elements of Chemical Engineering* (1936), New York
Baumgartner	*Canned Foods* (1949), London
Bell	*Law of the Sale of Foods* (1947), London
Bergey	*Manual of Determinative Bacteriology* (1948), Baltimore
Bibby	*Bibby's Book on Milk*, Liverpool
Bloor	*Biochemistry of the Fatty Acids* (1943), New York
Britton	*Hydrogen Ions* (1942), London
Buchanan and Fulmer	*Physiology and Biochemistry of Bacteria* (1928-30), London
Burke	*Practical Manufacture of Cultured Milks* (1938), Milwaukee, Wis.
Chalmers	*Bacteria in Relation to the Milk Supply* (1945), London
Clark	*The Determination of Hydrogen Ions* (1928), Baltimore
Clayton	*The Theory of Emulsions and their Technical Treatment* (1943), London
Cox	*The Chemical Analysis of Foods* (1950), London
Cronshaw	*Dairy Information* (1946), London
Crawford and Broadley	*The People's Food* (1938), London
Cunningham	*Practical Bacteriology for Students of Agriculture* (1947), London
Cuttell	*The H.T.-S.T. Plant* (1948), London
Davies	*The Chemistry of Milk* (1939), London
Demeter	*Dairy Bacteriological Methods* * (1952)
Drummond and Wilbraham	*The Englishman's Food* (1939), London
Enock	*This Milk Business* (1943), London
Eilers *et al.*	*Chemical and Physical Investigations on Dairy Products* (1947) Amsterdam
Evans	*Metallic Corrosion, Passivity and Protection* (1946), London
Eyre	*Bacteriological Technique* (1930), London
Farrall	*Dairy Engineering* (1945), New York
FIM	*Food Industries Manual* (ed. Crosbie-Walsh) (1951), London
Francis	*Bovine Tuberculosis* (1948), London
Gaiger and Davies	*Veterinary Pathology and Bacteriology* (1946), London
Gale	*Chemical Activities of Bacteria* (1951), London
Hammer	*Dairy Bacteriology* (1948), London
Harvey and Hill	*Milk Production and Control* (1946), London
Hilditch	*The Chemical Constitution of Natural Fats* (1947), London
House	*Bacteriological Control of Milk* (1931), Cambridge
Hill	*Pasteurisation* (1947), London
Hunziker (B)	*The Butter Industry* (1940), Le Grange, Ill.
Hunziker	*Condensed Milk and Milk Powder* (1949), Le Grange, Ill.
Jacobs	*Chemistry and Technology of Food and Food Products* (1951) London
Kon and Mawson	*Human Milk* (1950), H.M.S.O.
Levine and Schoenlein	*A Compilation of Culture Media* (1930), New York
Ling	*A Textbook of Dairy Chemistry* (1948), London
McCulloch	*Disinfection and Sterilisation* (1945), London
Miller and West (editors)	*Black's Veterinary Dictionary* (1953), London
Mojonnier and Troy	*The Technical Control of Milk and Milk Products* (1922)
Moncrieff	*The Chemical Senses* (1951), London
Nicholls	*Aids to the Analysis of Food and Drugs* (1952), London

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* In German.

CODE USED FOR BOOKS

Orla Jensen	*Dairy Bacteriology* (1931), London
Orla Jensen (*LAB*)	*The Lactic Acid Bacteria* (1919 and 1943), Copenhagen
Petersen	*Dairy Science* (1950), Chicago
Prescott and Dunn	*Industrial Microbiology* (1949), New York
Resuggan	*Quaternary Ammonium Compounds* (1951), London
Richmond	*Dairy Chemistry* (revised Davis and Macdonald) (1953), London
Roadhouse and Henderson	*The Market Milk Industry* (1950), N.Y.
Rogers	*Fundamentals of Dairy Science* (associates of L. A. Rogers) (1935), New York
SMDP	*Standard Methods for the Examination of Dairy Products* (1953), New York
Smith	*Introduction to Industrial Mycology* (1945), London
Stephenson	*Bacterial Metabolism* (1949), London
Sumner and Somers	*Chemistry and Methods of Enzymes* (1947), New York
Swift	*Food Administration* (1947), London
Totman, McKay and Larsen	*Butter* (1939), London
Tanner	*Microbiology of Foods* (1944), New York
Tyler	*Organic Chemistry for Students of Agriculture* (1946), London
Walworth	*Feeding the Nation in Peace and War* (1940), London
Watson and More	*Agriculture* (1951)
Whittier and Webb	*Byproducts from Milk* (1950), N.Y.
Williams	*Report of the Committee on Milk Distribution* (1948), H.M.S.O.
Williams, K. A.	*Oils, Fats and Fatty Foods* (1950), London
Wilson	*Pasteurisation of Milk* (1942), London
Wilson and Miles	*Principles of Bacteriology and Immunology* (Topley and Wilson) (1946), London
Wilson *et al.*	*Bacteriological Grading of Milk* (1935), H.M.S.O.
Wilster	*Practical Butter Manufacture* (1951) *Corvallis, Oregon.*
Winton and Winton	*Analysis of Foods* (1945), New York
Wright	*Agricultural Analysis* (1938), London

The author's other books are referred to by name: *Milk Testing*, *LCDP* (*Laboratory Control of Dairy Plant*)

CODE USED FOR JOURNALS, ETC.

Code	Journal
A	*Analyst*
AJDT	*Australian Journal of Dairy Technology*
AJPH	*American Journal of Public Health*
AMR	*American Milk Review*
AP	*Agricultural Progress*
ARB	*Annual Review of Biochemistry*
ARM	*Annual Review of Microbiology*
BJ	*Biochemical Journal*
BIOS	*British Intelligence Objective Series*
BJN	*British Journal of Nutrition*
BR	*Bacteriological Reviews*
BS	*British Standard* (British Standards Institution)
CDIC	*Canadian Dairy and Ice Cream Journal*
CI	*Chemistry and Industry*
D	*Dairyman*
DF	*Dairy Farmer*
DI	*Dairy Industries*
DM	*Deutsche Molkereizeitung*
DSA	*Dairy Science Abstracts*
DSIR	*Dept. of Scientific and Industrial Research*
F	*Food*
FM	*Food Manufacture*
FR	*Food Research*
IDC	*International Dairy Congress*
IEC	*Industrial and Engineering Chemistry*
IJDS	*Indian Journal of Dairy Science*
JAOAC	*Journal of the Association of Official Agricultural Chemists, Washington*
JAS	*Journal of Agricultural Science*
JB	*Journal of Bacteriology*
JCPT	*Journal of Comparative Pathology and Therapeutics*
JDR	*Journal of Dairy Research*
JDS	*Journal of Dairy Science*
JH	*Journal of Hygiene*
JMFT	*Journal of Milk and Food Technology*
JRSI	*Journal of the Royal Sanitary Institute*
JSCI	*Journal of the Society of Chemical Industry*
JSFA	*Journal of Science of Food and Agriculture*
JSDT	*Journal of the Society of Dairy Technology*
LP	*Laboratory Practice*
M	*Milchwissenschaft*
MBMH	*Monthly Bulletin of the Ministry of Health and the Public Health Laboratory Service*
MD	*Milk Dealer*
MI	*Milk Industry*
MP	*Mol Prom*
MPM	*Milk Plant Monthly*
N	*Nature*
NIRD	*National Institute for Research in Dairying, Report*
NMDJ	*Netherlands Milk and Dairy Journal*
PRS	*Proceedings of the Royal Society*
PSWTE	*Proceedings of the Society for Water Treatment and Examination*
R	*Research*
S	*Science*
SAB	*Proceedings of the Society for Applied Bacteriology*
VR	*Veterinary Record*

ACKNOWLEDGMENTS

THE author gratefully acknowledges permission to make use of extracts, tables, etc., from the following :—

British Standards Institution (*Sampling*).
Her Majesty's Stationery Office (*Bottles, tests for sterility*, Crown Copyright).
Milk Industry Foundation and Mr. R. J. Winning (*Pasteurisation*).
Dr. G. S. Wilson and Messrs. Arnold (*Pasteurisation*).

He also expresses his thanks to all those firms, institutions and scientists who have helped so willingly in providing photographs and illustrations.

He is greatly indebted to Mr. W. Leonard Hill, Mr. T. Crosbie-Walsh and Mr. R. G. Thixton for their valuable help and advice, and to his wife and Miss D. Knight for their co-operation at all stages in the preparation of this book.

PREFACE TO THE FIRST EDITION

THE aim of the author of this work has been to write in the first place a work of ready reference that would be of interest to, and understood by, any scientist in other fields and any intelligent layman in the dairy industry. With most subjects the bare minimum of information has been provided together with suggestions for further reading. Some subjects, however, have received more extensive treatment than others because of the lack of suitable treatment elsewhere. A large proportion of these longer sections has been based on the personal experience and work of men and women who have acquired specialist knowledge through a life-time's acquaintance with the subject on which they have written. These sections have been specially written for this dictionary, and I should like to place on record my great appreciation of their efforts and their interest in this book.

Owing to present restrictions it has not been possible to deal adequately with all subjects. Consideration has been given to the fact that some subjects such as pasteurisation, nutritive values, and dairy farming have been extensively written about in the last year or two. Consequently, they have not received the attention in this first edition that they would otherwise have had. Such subjects will be more adequately dealt with in succeeding editions. The author has endeavoured to make this work complementary to the existing literature.

Since this dictionary has been written primarily for English-speaking countries, references have been purposely largely limited to those journals likely to be available in the British Commonwealth.

J. G. DAVIS.

LONDON, 1949.

PREFACE TO THE SECOND EDITION

THE most important change is the addition of several articles by leading authorities on those subjects which were only slightly dealt with in the first edition. The references have been brought up to date and outstanding changes since 1950 have been noted.

I express my most grateful thanks to all contributors in this new edition for their whole-hearted co-operation.

J. G. DAVIS.

READING, *July* 1952.

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SUGGESTIONS FOR STUDENTS AND OTHERS PREPARING FOR EXAMINATIONS

The more important subjects may be surveyed by reading entries in the Dictionary as below :—

1. **CLEANING, STERILISING, Etc.**
   Bottle washing; Chlorine; Churns, cleaning; Cleaning and Sterilising; Detergents; Dirty churns; Pasteurisation; Quaternary ammonium compounds; Sterilisation of utensils; Surface to volume ratio; Water.

2. **DAIRY BACTERIOLOGY**
   Bacteriological equivalents; Bacteriological grading; Bottles, tests for sterility; Bottle washing; Churns, cleaning; Cheese, pp. 168-219; Classification; Clean milk production; Coliforms; Cooling; Detergents; Dirty churns; Diseases; Disinfectants; Effluents; Food poisoning; Laboratories; Lactic acid bacteria; Mastitis; Pasteurisation; Pasteurisation, alternatives to; Platform testing; Refrigeration; Resazurin; Ropy milk; Routine tests; Stability; Starters; Sterilisation; Thermoduric bacteria; Thermophilic bacteria; Water.

3. **DAIRY BIOCHEMISTRY AND PHYSIOLOGY**
   Abnormal milk and Mastitis; Composition, factors affecting; Digestion; Enzymes; Flavours; Hormones; Milk secretion; Nutritive value; Rennet; Vitamins.

4. **DAIRY CHEMISTRY**
   Abnormal milk; Acidity; Annatto; Auto-oxidation; Bottles; Calibration; Casein; Constituents; Detergents; Effluents; Fatty Acids; Fishiness; Freezing point test; Heat, effect on milk; Laboratories; Phosphatase test; Quinhydrone electrode; Routine tests; Solids-not-fat; Standards (chemical); Testing of milk supplies; Water; Whey.

5. **DAIRY FARMING**
   Abnormal milk; Agriculture; Bail; Breeding; Clean milk production; Cleaning and sterilising; Composition, factors affecting; Cooling; Costings; Digestion; Dairy farm buildings; Feeding of dairy cattle; Grass; Management of dairy cattle; Mastitis; Milk marketing; Milk secretion; Milking machines; Quality milk production; Quality payment; Refrigeration; Ropy milk; Transport; Water.

6. **DAIRY ENGINEERING**
   Bottle filling and capping; Bottle washing; Brine; Churns, cleaning; Cooling; Effluents; Electrical equipment; Instrumentation; Management of creameries; Management of pasteurising depots; Metals; Pasteurisation; Pumps; Refrigeration; Various metals (by name); Water.

7. **DAIRY PHYSICS**
   Bottles; Calibration; Detergents; Fat globules; Instrumentation; Physical properties (by name); Rheology.

8. **FAULTS IN DAIRY PRODUCTS**
   Abnormal milk and Mastitis; Butter; Cheese, p. 168; Coliforms; Colour faults; Condensed and evaporated milk; Flavours; Food poisoning; Ice cream; Insecticides; Milk powder; Pasteurisation; Refrigeration; Ropy milk; Souring and Acidity; Stability, microbiological; Sterilised milk; Sweet curdling; Thermoduric bacteria; Thermophilic bacteria; Various faults (by name).

9. LABORATORY TESTING

Accuracy; Bacteriological grading of milk; Calibration; Coliforms; Detergent concentration; Effluents; Fat, determination of; Freezing point test; Laboratories, organisation of; Legal aspects; Media; Methylene blue test; National Milk Testing Scheme; Phosphatase test; Plate-count; Platform testing; Quality payment; Resazurin tests; Routine laboratory tests; Sampling of dairy products; Solids-not-fat; Testing of milk; Water.

10. MANAGEMENT

Bottles; Bottle filling and capping; Bottle washing; Cartons; Churns, cleaning; Clean milk production; Cleaning and sterilising; Composition of milk; Cooling; Costings; Dairies, design of; Dirty churns; Effluents; Electrical equipment; Fallacies; Farm advisory work; Feeding; Flavours; Heat, effect on milk; Legal aspects; Management of creameries; Management of pasteurising depots; Mechanical handling; Milk marketing; Milk (Special Designations) Order; Pasteurisation; Platform-testing; Production of milk; Quality milk production; Quality payment; Refrigeration; Retail dairying; Routine laboratory tests; Sampling of dairy products; Stability; Standards (chemical); Sterilised milk; Testing of milk supplies; Transport; Utilisation; Water.

11. MANUFACTURE

Abnormal milk; Annatto; Butter; Butter, renovated; Butter-making machines; Margarine; Milk powder; Packaging; Pigs; Refrigeration; Rennet; Stability; Starters; Sterilised milk; Utilisation; Water.

12. MEDICAL, VETERINARY AND PUBLIC HEALTH ASPECTS

Bottle washing; Churns, cleaning; Clean milk production; Coliforms; Detergents; Diseases, human; Diseases of dairy cattle; Effluents; Enzymes; Food poisoning; Haemolytic streptococci; Mastitis and Abnormal milk; Milk secretion; Pasteurisation; Sterilisation; Tuberculosis; Water supplies.

13. NUTRITIONAL ASPECTS

Abnormal milk; Breadmaking; Butter; Cheese, p. 168; Composition, factors affecting; Condensed and evaporated milk; Constituents; Feeding; Heat, effect on milk; Ice cream; Infant foods; Milk marketing; Milk powder; Nutritive values; Pasteurisation, p. 786; Sterilised milk; Utilisation; Vitamins; Whey.

14. ADMINISTRATIVE, ECONOMIC AND LEGAL ASPECTS

Costings, processing and distribution; Dairies, design of; Ireland, Northern; Legal aspects; Management of creameries, of pasteurising depots; Milk marketing; Retail dairying; Scotland; Utilisation; Wales; World production.

A

ABBÉ REFRACTOMETER. *See* Refractive index.

ABNORMAL FLAVOURS. *See* Flavours.

ABNORMAL MILK (Mastitis Milk). This general term is used to describe any type of milk that differs markedly from ordinary milk. In its restricted sense it is used to describe milk from the udder that is abnormal on account of udder disease or mastitis. Such milk is commonly low in solids-not-fat and sometimes in fat, low in lactose and calcium, and high in sodium chloride. The casein : globulin ratio is also low, and the *p*H high and titratable acidity low.

The following definitions of abnormal milks have been suggested (Barron, Davis and McClemont (1939) *AP*, **16,** 23):

Economically Abnormal. (i) Colostrum (especially up to three days, and to some extent up to fifteen days). (ii) Late lactation milk (usually after about eight months). (iii) Tainted milk, *e.g.* due to feeding cows on certain foods.

Physiologically Abnormal. (iv) Malnutrition milk—this becomes normal on supplying the animals with a proper diet. One example is milk not clotting with rennet, but clotting normally when the animal is given succulent foodstuffs.

Pathologically Abnormal. (v) Mastitis milk—containing *Str. agalactiæ* on secretion. Such milk may show no visual change and no significant biochemical abnormality. (vi) Other types of mastitis milk defined by name, *e.g.* due to staphylococci, *Str. dysgalactiæ*, *Str. uberis*, *Myco. tuberculosis*, *Br. abortus* (?), or in fact any organism capable of causing tissue response. (vii) Biochemically abnormal milk—milk biochemically abnormal in at least one respect, but containing no organisms known to cause mastitis. Previous or subsequent history may reveal the cause to be mastitis. (viii) Metabolically abnormal milk—due to an inborn error of metabolism. It may be impossible to distinguish this from (vii). There is no legal or scientific definition of abnormal milk, but the Rapid Abnormality Indicator (p. 886) affords a simple method of assessment. Alternatively the chloride-lactose ratio may be used (p. 222). Visually abnormal milks, *i.e.* flaky, stringy, watery, or discoloured milks, constitute clinical cases of (v) and (vi).

Testing for Abnormal Milk. While the treatment and eradication of mastitis require expert bacteriological examination and veterinary service, it is possible by simple tests to pick out cows giving abnormal milk, and so possibly affecting the behaviour of the bulk in the official tests under the Joint Milk Quality Control Committee's Scheme. Of all the tests available the resazurin, and especially the resazurin-rennet tests, are perhaps the most useful as they give the maximum of information in the least time. It is not always clearly understood why the resazurin test can be used for detecting "mastitis" or abnormal milk, for examining milk on the platform and for grading milk in the laboratory. The reason is as follows:

Milk fresh from the udder contains very few bacteria and very few cells in the absence of mastitis. Mastitis results in a considerable increase in the number of cells and also in the number of bacteria in milk *inside the udder.* A resazurin test on freshly drawn milk therefore measures almost entirely cells, and the worse the mastitis the quicker is the dye reduced or changed from blue to pink. Colostrum and late lactation milk also reduce resazurin to some extent, but in this case all four quarters are affected and, of course, the cowman is aware of the condition. The effect of oestrus is very slight. Broadly speaking, the more the cells the quicker the reduction of resazurin, but leucocytes and active cells are more potent than dying cells and cell debris. Mastitis also results in a slow clotting by rennet, so that the resazurin-rennet test, which is very easily carried out, gives information about both the number of cells *and* the chemical abnormality of the milk (alkalinity, etc.). Such milk is also frequently low in solids-not-fat.

Inter-relation of tests. Very bad samples will reduce resazurin rapidly and fail to clot with rennet. If a sample clots slowly with rennet but does not reduce resazurin, it may indicate a past history of mastitis. A change of colour of resazurin without slow clotting may indicate an incipient infection which should receive treatment at once.

Why test cows for abnormal milk ? The producer who has owned a dairy herd for many years may ask why it should be worth while for him to get his cows tested in this way. There are a number of reasons which make this worth while.

Most owners of dairy herds have no certain knowledge of the quality of milk given by each cow. Clinical cases are, of course, obvious and an intelligent milker will detect the small clots in slightly affected milk.

(*a*) *Economic Advantages.* Infected cows are inefficient converters of food to milk. Not only is the yield depressed (*e.g.* by 20 per cent.) but the solids in the milk are lowered, particularly the solids-not-fat.

(*b*) *Danger of Low Solids-not-fat.* The legal limit is 8·5 per cent. and many Friesian and some Shorthorn herds give milk that is dangerously near this limit. In practice it is found that failure to reach this level may be due to a combination of a low solids breed, such as Friesian, and mastitis. (This is, of course, apart from cases of watering.) Should a producer receive a warning on account of low solids-not-fat, his first action should be to test his cows individually either by the resazurin-rennet test or a solids-not-fat test. The two tests usually go together.

In one experiment the following results were obtained :

Average S.N.F. of cows passing resazurin test	8·56
Average S.N.F. of cows failing resazurin test	7·90
Average S.N.F. of cows passing rennet test	8·58
Average S.N.F. of cows failing rennet test	7·93

(*c*) *Danger of Infecting Other Cows.* While the resazurin-rennet test is not an accurate test for milk containing mastitis organisms, it will pick out the bad cases, which may be segregated or disposed of, or milked last. It is better than no test at all for this purpose.

(*d*) *Effect on Bacterial Count.* Abnormal milk almost invariably contains many more bacteria than healthy milk. When the methods of production are bad and the milk would, for example, reduce resazurin completely in one hour, it is true that the " mastitis effect " is relatively small, as the chief sources of the bacteria are the unsterile utensils, dust, dung, etc. With a good producer a few unsound cows may be the cause of unsatisfactory results in the plate count. When a good producer suddenly gets a high count, especially if low in coli, some experienced creamery bacteriologists suggest that mastitis is a probable cause of the trouble, and they are frequently right.

In view of the inevitable " clean up " of the milk supply of the country and the raising of the bacteriological standards for milk, it is obvious that, when the grosser sources of contamination such as dirty utensils have been eradicated, the importance of mastitis as a cause of high counts in milk will increase. It will therefore pay producers to have an eye to the future from this point of view alone, apart from the economic and animal health aspects.

(*e*) *Effect of Abnormal Milk on Manufacture of Milk Products.* When used for liquid consumption the possible drawbacks of such milk are limited to its lower nutritional value, provided that the milk is pasteurised, although a consumer might rightly object to drinking a fluid rich in animal cells and dead streptococci and staphylococci. Manufacturers and especially cheesemakers, however, have a much more serious objection to abnormal milk as it leads to such troubles as weak body, slow starter in cheese and other faults if the proportion rises above 10 or 15 per cent.

Farmhouse cheesemakers are therefore advised to test all their cows once a week in the making season by some simple test such as the bromcresol purple or resazurin-rennet test, or by the Rapid Abnormality Indicator (p. 886).

Manufacturers of cheese and condensed milk would be well advised to test their milk supplies by the resazurin-rennet test twice a month, and to use for other purposes milk failing to clot with rennet in twice the time required to clot normal milk. *See* Mastitis.

ABOMASUM. The fourth or true stomach of ruminants. *See* Cow, internal organs of; Digestion in the ruminant; Enzymes; Rennet.

ABORTION, CONTAGIOUS. This disease is a cause of serious loss to the dairy farmer and is caused by *Brucella abortus*, an organism closely related to the organism of undulant or Malta fever, *Brucella melitensis*. Its presence in milk is most easily detected by guinea-pig inoculation, but it can be isolated by inoculating infected milk into serum or liver agar containing gentian violet (1 in 200,000) and incubating at 37° in 10 per cent. CO_2. About 25 per cent. of samples of market milk are stated to be infected, but the number of reported cases of undulant fever is small. Some pathologists consider that many mild cases are never recognised as such by the general practitioner. The organism occurs in the blood of affected animals and so reactors can readily be detected by an agglutination test. *See* Diseases; Undulant fever.

Refs: Miller; Gaiger and Davies; Wilson and Miles; Wilson; Stableforth (1952) *Proc. R. Soc. Med.* **45**, 79; Seelemann and Meyer (1950), *M* **5**, 221 (chemotherapy).

ABRASION. The roughening, scratching or indenting of a surface by mechanical action. Resistance to abrasion is a most important property in metals in use in the dairy industry as crevices must be avoided on account of bacterial growth. Hardness is not the only property concerned; elasticity and other properties play a part. It is important to avoid a hard or tough metal knocking against a softer metal, *e.g.* steel against aluminium. *See* Metals.

Ref.: Evans.

ABSORPTION. A general term for the inclusion of a material in another, not to be confused with Adsorption (p. 12).

In dairying the phenomena of chief interest are (i) the absorption of odours by milk (*see* Flavours); (ii) the absorption of milk and bacteria by rubber and other similar materials, especially teat cup liners and milk lines (*see* Cleaning; Detergents; Milking machines); (iii) the absorption of foods by the cow (*see* Digestion; Enzymes; Feeding).

ABSORPTION OF LIGHT. A coloured material will absorb certain light rays depending on the chemical structure and colour. Thus whey appears greenish because of the riboflavin. Such absorption can lead to catalysed reactions involving the destruction of colourless substances by sunlight, *e.g.* vitamin C in milk. *See* Flavours; Fluorescence; Nutritive aspects; Vitamins.

ABSORPTION NUMBER, IODINE. Unsaturated fats and fatty acids can absorb a certain amount of iodine and this quantity is characteristic for the fatty acid. In butter oleic acid is chiefly concerned, and the iodine values vary from 30 to 40. *See* Auto-oxidation.

Refs.: Hilditch; Williams (K. A.); Richmond; Arup (1932), *A*, **57**, 610.

ABSTRACTION OF FAT. The abstraction of fat and addition of water are the two common ways of defrauding the buyer. While the addition of water can readily be detected by the freezing-point test (p. 485), there is no simple way of proving that fat has been removed on account of the highly variable amount in milk. Milk that contains less than 3 per cent. fat is presumed to be adulterated or not genuine until the contrary is shown and it is, of course, an offence to remove fat or any other constituent from milk. Low fat in milk may also be due to *bona fide* causes (*see* Composition) or to failure to mix a bulk properly or, quite commonly, to failure to strip properly after milking. The practice of putting a calf to a cow following incomplete stripping raises a difficult point in law. *See* Legal aspects; Quality payment; Standards, chemical.

ABSTRACTS OF THE LITERATURE. Abstracts of scientific and technical papers appear in (i) *Dairy Science Abstracts;* (ii) *Journal of Dairy Science* (American); (iii) *Journal of the Science of Food and Agriculture;* (iv) *Chemical Abstracts* (American) ; (v) *Manuale lactis* (Schulz) (German). *See* Literature.

ACCOUNTS. *See* Costings; Management of dairies.

Ref.: Locke (1948), *JSDT*, **1**, 171.

ACCREDITED MILK. This grade disappears on 1st October, 1954. *See* Legal aspects; Milk Marketing; Quality payment; Scotland.

ACCURACY. It is not always appreciated by the non-technical worker in the dairy industry that no practical measurement or laboratory test is ever *absolutely* accurate. There is always an error. Broadly speaking physical measurements are the most accurate, chemical analyses usually sufficiently accurate for their purpose, and bacteriological tests easily the most uncertain, and least dependable of all tests on account of the inherent unpredictable behaviour of micro-organisms. The probable error of a single measurement, or of a known number of replicate measurements, can be calculated statistically (*see* Statistical formulae). The practical implications of error are illustrated in Table Ac I.

A point of considerable importance is the calculation of the total weight of fat in a large volume of milk from the results of Gerber tests on 11 ml. portions from 3000 gallons. For example, if 9000 gallons of milk are converted to butter daily for three months the possible error in calculating the total fat is

$$\frac{0{\cdot}05 \times 9000 \times 44 \times 90}{450} = 4000 \text{ lb.}$$

Thus in a large creamery an error of up to 2 tons *may* arise over three months due entirely to the normal error of laboratory testing. These errors, like other errors, usually cancel out over a period but their possible significance is not always realised by managers and accountants. Similar discrepancies may arise through conversion errors, *e.g.* volume to weight, gravity measured under various conditions, etc.

TABLE Ac I

(Typical values quoted)

Measurement	*Magnitude*	*Error*	*Error as % of quantity measured*
Length	10 in.	1/32 in.	0·3
Temperature	160° F.	1/4° F.	0·25 *
Total solids (gravimetric) . .	12·5 %	0·02 %	0·2
Fat (Röse-Gottlieb) . . .	3·7 %	0·02 %	0·5
Fat (Gerber)	3·7 %	0·05 %	1
Solids-not-fat (lactometer) . .	8·8 %	0·1 %	1
Bacterial count (plate count) .	100,000	20,000	20
Methylene blue test . . .	3 hr.	1/2 hr.	17

* Arbitrarily expressed as a percentage of the difference between 160 and 60° F.

ACETIC ACID. Acetic acid $CH_3.COOH$ is the second lowest member of the fatty acid series and is the chief acid constituent of vinegar. Its importance in dairying lies in the fact that it is the chief secondary product in the lactic acid fermentation and so is an important flavour constituent in nearly all dairy products. *See* Cheese ; Fatty acids ; Flavours ; Lactic acid bacteria.

Ref.: Prescott and Dunn.

ACETIC ACID BACTERIA.

Refs.: Bergey; Prescott and Dunn; Järvik (1953), *IDC*, **2**, 507 (in butter).

ACETOIN (Acetyl Methyl Carbinol). This substance has the formula

$$CH_3 . CO . CH(OH) . CH_3,$$

and is of considerable interest as the precursor of diacetyl, the aroma substance of cream and butter. *See* Butter ; Cheese ; Coliforms ; Flavours ; Lactic acid bacteria.

Ref. : Prescott and Dunn.

ACETONAEMIA. The presence of acetone bodies in the blood. It indicates excess of fatty foods or excessive feeding or a metabolic disorder.

Ref.: Robertson *et al.* (1950), *N*, **166**, 954.

ACETONE. The simplest ketone $CH_3 . CO . CH_3$. It has a characteristic odour and is present in diabetic urine, blood and breath. It can be detected in the breath of cows if the feed is deficient in carbohydrate due to the failure of the animal to oxidise completely the fatty material. *See* Flavours.

ACHROMOBACTERIUM. A genus of gram-negative, non-pigment forming, non-spore forming rods, attacking proteins and fat and causing taints in butter. *See* Classification.

Ref. : Bergey.

ACID CASEIN. Casein precipitated by adjusting the *p*H of the solution to *c.* 4·6. *See* Casein.

Refs. : Whittier and Webb ; Davies ; Rogers.

ACID-BASE EQUILIBRIA. Practically all aqueous solutions contain substances having acid or basic (alkaline) properties and the resultant equilibrium defines the *p*H or hydrogen ion concentration (p. 511) which is of the greatest importance in dairying, being a major factor in the stability and keeping quality of all dairy products. *See* Acidity of milk ; Buffers.

Refs. : Britton ; Clark ; Rogers ; Davis (1950), *F*, **19**, 44, 84, 146.

ACID-FAST BACILLI. *See* Classification ; Mycobacterium.

Ref. : Wilson and Miles.

ACIDIMETER. In an endeavour to standardise the determination of the titratable acidity of milk a special acidimeter has been devised based on the recommendation of using 20 ml. of milk, whey, etc., and 2 ml. of 0·5 per cent. indicator. The acidimeter consists of the following components : (*a*) A special burette marked to read $\frac{1}{20}$ the true amount so that with 20 ml. milk the burette reading gives a direct value for " per cent. lactic acid ". (*b*) A second burette etched every 1 ml. but unnumbered. (*c*) A reservoir bottle for $\frac{N}{9}$ NaOH. (*d*) A reservoir bottle for 0·5 per cent. phenolphthalein in 50 per cent. alcohol. (*e*) Rubber tubing, glass tube joints, spring clips, etc. (*f*) A special stand or rest for the record book. (*g*) A suitable open-work frame for supporting the burettes and reservoirs. (*h*) Two white basins, flat-bottomed and non-rollable. (*i*) Stirring rods. (*j*) 20 ml. pipettes.

Method of Use. The sample is well shaken and 20 ml. transferred to a dish. A second dish also receives about 20 ml. milk and serves as a control for the end-point. The 20 ml. milk is then placed under the left-hand burette and 2 ml. of indicator added. It is then moved to beneath the right-hand burette, in which the soda is adjusted to the zero mark, and titrated steadily, the milk being stirred with a glass rod. When the milk assumes a greyish tinge the soda is added drop by drop until a slight but definite difference (faint grey-pink) in colour from the control is noticeable. The burette reading is then recorded as " per cent. lactic acid ". *See* Acidity, titratable, technique for.

ACIDITY OF MILK. Temperature and acidity (hydrogen ion concentration or *p*H) are the two most important factors controlling the behaviour of milk and its derivatives in the various processes employed in the dairy industry. The peculiar properties of acids or acidic substances in solution lie in the possession of hydrogen bound in such a way that it can readily split off and become a hydrogen ion. In different acids the degree of this splitting-off (or dissociation) varies considerably, and defines the strength of the acid, since acidity is due to hydrogen ions. The unit of acidity is the concentration of these ions or wandering hydrogen atoms, actual and potential, measured in grams per litre, and unit weight of an acid is that weight of acid which contains 1 g. of ionisable hydrogen, or alternatively contains 1 g. of hydrogen that is replaceable by a metal or that can be neutralised by an alkali or base. The acidities which occur in dairying practice are due to rather small concentrations of hydrogen ions. Thus when a milk is just clotting because bacteria have soured it, the hydrogen ion concentration is about 1/100,000 g. per litre, *i.e.* milk clots at about *p*H 5. We are all familiar with the fact that the acidity of fresh milk is stated to be usually about 0·14 per cent. lactic acid. Now fresh milk contains no lactic acid, and is nearly neutral. Why do we express the acidity of milk in this way ?

Strong and Weak Acids. In Fig. Ac 1 are given curves showing *p*H (or true acidity) values for acid solutions that are being neutralised by an alkali. Curve A shows the relationship between *p*H and the degree of neutralisation of a strong acid (hydrochloric acid) and curve B that between *p*H and the degree of neutralisation of a weaker acid such as lactic acid. In the first case little change in *p*H occurs until nearly all the acid is neutralised, when the *p*H mounts from quite low to quite high values. In the second case there is a kink in the curve. This kink occurs at a point when half the acid is neutralised, and the weaker the acid the higher is the *p*H at which the kink occurs. It is evident that at this " kinking point " quite large amounts of alkali (or acid) could be added without much effect on the *p*H. The acid acts as a buffer against the alkali added, but only in this *p*H region. This property is called the buffering power of the acid and it may be measured by the quotient :

$$\frac{\text{amount of alkali (or acid)}}{p\text{H change}} \text{ at any given } p\text{H}.$$

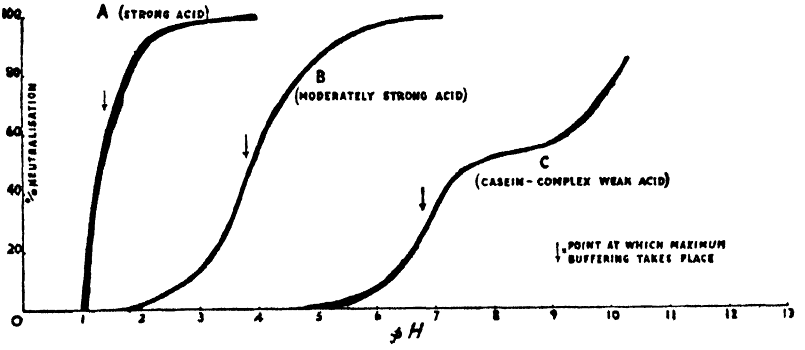


FIG. Ac 1.

Now phosphoric acid (one of the most important in milk) has three hydrogen atoms all capable of ionising. It is an acid three times over and behaves, in fact, as a strong acid, weak acid, and as a very weak acid. There are thus three kinks in the titration curve of phosphoric acid (Fig. Ac 2, curve A, p. 7), which can buffer at three different *p*H values. Citric acid is similar, but here the three hydrogen atoms are so bound that the degrees of dissociation differ only slightly. The kinks in the titration curve therefore merge one into the other, giving a straight line between *p*H 3 and *p*H 6. Citric acid thus buffers continuously over this range (Fig. Ac 2, curve B). It is evident that if we add alkali to a solution of an acid until an indicator which changes colour right on the alkaline side begins to " turn ", we are, in fact, measuring the amount of acid present. A large proportion of this alkali will be used, however, to change the acidity or *p*H over the range of buffering of the acid. The amount of alkali (or acid) necessary to change the *p*H of such a solution partly neutralised depends, therefore, not only on the amount of acid present, but also on what point on the titration curve we are working, *i.e.* the percentage neutralisation. The maximum buffering occurs when the acid is 50 per cent. neutralised.

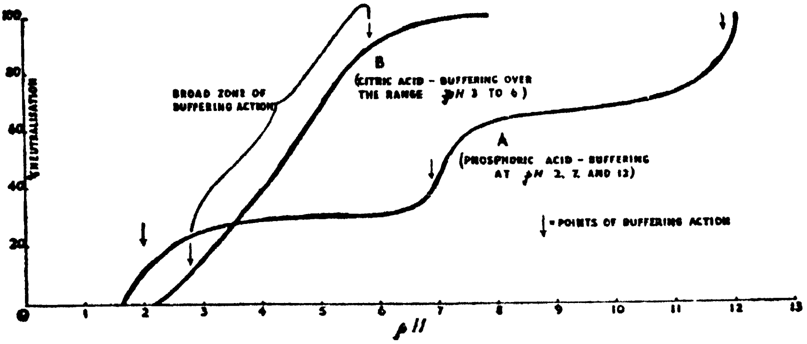


FIG. Ac 2.

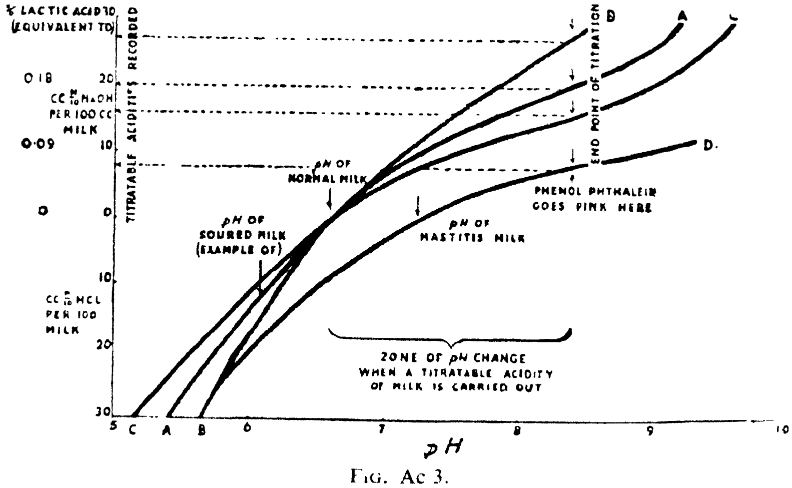


FIG. Ac 3.

Now milk is, in fact, very largely a mixture of partly neutralised weak acids, the most important being : (1) phosphoric acid and (2) casein and other proteins which behave as weak acids. Citric acid and carbonic acid are quantitatively much less important. We have seen that phosphoric acid buffers at *p*H 2, 7 and 12, and casein buffers most strongly at *p*H 6 to 7·5. We should expect the titration curve of milk to show a broad " kink ", or bend, at about *p*H 7, indicating a higher buffer value in this zone. Such is actually the case. A typical titration curve is shown in Fig. Ac 3 (curve A). It should be observed that fresh milk has a *p*H value of about 6·6, and phenolphthalein changes colour (goes pink) at about *p*H 8·4. What we really do, therefore, when we titrate the " acidity " of fresh milk is to find out how much alkali is required to change the *p*H from 6·6 to 8·4. If the milk sours on account of bacterial activity, an increased quantity of alkali is required, and so the acidity or titration value of the milk increases (Fig. Ac 3). Whereas the former value is largely a measure of the phosphates and protein in the milk, the latter is a measure of this *plus* the formed lactic acid. Thus to get an idea of the amount of lactic acid in a soured milk we must subtract the former value from the latter.

The value of the initial acidity lies in its usefulness as a measure of the richness or solids-not-fat in the milk, since the more phosphate and protein in the milk, the more alkali is required to overcome their buffering power over the range *p*H 6·6 to 8·4.

This is illustrated in Fig. Ac 3, which shows diagrammatically the titration curves of various types of milk. Curve A shows the course of " neutralisation " of the milk phosphate, casein, etc., when the " titratable acidity " of normal milk is determined.

Curve B shows the curve for a milk of high solids-not-fat such as Jersey milk. It will be noticed that more alkali is required to change the *p*H from 6·6 to 8·4, and so a higher " titratable acidity " is recorded. The *p*H values or true acidity values of the milks are, however, identical.

Curve C shows a poorly-buffered milk, low in solids-not-fat. A correspondingly low " titratable acidity " is, therefore, obtained, although, like milks A and B, it possesses a normal *p*H value.

Curve D is interesting because it illustrates the fundamental difference between the effects of " buffer value " and of true acidity or *p*H on the titratable acidity.

Curve D is typical of " mastitis milk ", or milk taken from a quarter infected with *Str. agalactiæ*. Such a milk may have a titratable acidity of 0·10 per cent. lactic acid or even less. From the point of view of acidity it may be regarded as ordinary milk to which a little free alkali has been added. The *p*H, or true acidity, of the milk is therefore altered, and the titration with alkali starts at a point on the curve nearer to the end-point of phenolphthalein (8·4). In the example illustrated the " mastitis milk " is seen to have a *p*H of 7·2. It is this alkalinity which permits the use of brom-cresol-purple papers for detecting mastitis, although not all cases give a positive reaction to brom-cresol purple.

The " titratable acidity " of milk, then, is really that amount of lactic acid equivalent to the alkali required to change the *p*H from the normal (usually about 6·6) to about 8·4. It is a measure not only of the true acidity (or *p*H), but also of the buffering power (chiefly phosphate and casein) of the milk over this *p*H range. The titration is sometimes employed as a routine test for " weeding out " milk which has begun to sour. It is evident, however, that a high titratable acidity (T.A.) may indicate not only a slightly soured milk, but also a rich milk.

Further, a mixture of milk from " mastitis " cases, or of low solids-not-fat milk with normal milk, may be slightly soured and yet give a normal value (0·14 per cent. lactic acid) ; the T.A. figure, therefore, requires caution in its interpretation.

Since the heat stability of milk is primarily a function of its *p*H, and not its T.A., it is clear that it is wrong to condemn a milk solely on the grounds of a high T.A. The simplest test is smelling, and our senses are frequently many more times sensitive than ordinary chemical tests. Experienced " inspectors " can reject milk on smell alone. Moreover, the quality or richness of the milk received from various farms will be well known, and those milks with consistently high T.A. can " stand up " to more lactic acid than ordinary milk on account of their higher buffer values, *i.e.* it requires more lactic acid than ordinary milk to bring the *p*H down to a given value.

For really accurate control work a simple method of *p*H measurement affords valuable complementary information to the T.A. test. Thus the alcohol-alizarin test is really of more use for processing factories than the titratable acidity test. This test consists in adding a mixture of alizarin (an indicator that is reddish at *p*H 6·6, yellow on the acid side and violet on the alkaline side) and alcohol to milk. If the milk is soured the alizarin goes brown or yellow, and the combined effects of acid and alcohol precipitate the casein in the milk. The results given by the two tests are shown below:

Result by T.A. test	*Result by alcohol-alizarin test*	*Conclusion*
Normal (0·14 per cent.)	Normal, lilac red	Normal milk
High (0·16 per cent.)	Acid, yellow brown	Milk soured
High (0·16 per cent.)	Normal, lilac red	Rich milk, not soured
Low (0·12 per cent.)	Normal, lilac red	Milk of low S.N.F.
Low (0·12 per cent.)	Alkaline, violet	" Mastitis " milk

More accurate information is obtained by determining the *p*H of the milk, but the alizarin test gives sufficient information for ordinary practical purposes.

One aspect that is not generally realised is the fact that the heat destruction of bacteria is governed by the *p*H (or true acidity) of the medium. Bacteria are more readily killed as the acidity rises. Hence the efficiency of pasteurisation may be dependent on the *p*H of the milk.

Another point of great practical importance is the solubility of metals in milk. Differences in acidity may result in variation in the rate at which copper, tin, etc., are dissolved.

Finally, it may be asked : " Should not the use of ' per cent. lactic acid ' figures be discontinued, since these are mostly nonsense? " It is almost certain that ultimately all those concerned with milk control will think in terms of *p*H and buffer value. For the present, however, the conception of " per cent. lactic acid " may continue to serve its purpose until *p*H measurements are general in the industry. Before this can be attained a simple, foolproof method of *p*H measurement must be made available for technical control purposes. This combined with " titratable acidity " measurements carried out under standardised conditions will afford much information about the quality of the milk under test. *See* Buffers ; Degrees ; Hydrogen ion concentration ; Quinhydrone electrode.

ACIDITY, TITRATABLE, TECHNIQUE FOR.

Cream. There is no official method, but the following may be used :

Weigh out 10 ± 0·05 g. cream into a white porcelain dish ; add 10 ml. distilled water and 1 ml. 0·5 per cent. phenolphthalein. Titrate with $\frac{N}{9}$ NaOH until a very faint pink colour is obtained. The titre gives the " per cent. lactic acid ". This determination is of great importance in buttermaking, as ripened (*i.e.* soured) cream butter is of richer flavour but poorer keeping quality than sweet (*i.e.* unsoured) cream butter. For quick routine tests 10 ml. may be ejected from a blow-out pipette. *See* Butter.

Milk. Although titration of milk with alkali is commonly used for measuring the degree of souring, the initial acidity of milk (about 0·14 per cent. " lactic acid ") is entirely due to the buffering action between *p*H 6·6 and 8·4. From this point of view we may regard milk as a mixture of partly neutralised weak acids, of which phosphoric and the proteins are the most important. Only by subtracting the initial acidity from the measured acidity can we accurately assess the degree of souring. Not only do the acidities of herd milks vary according to season, feed, etc., but there are individual variations. Mastitis and watering both lower the acidity, and for this reason the acidity test for hygienic quality is unreliable. *See* Acidity, titratable.

Bulk milk is of fairly uniform chemical quality and so the T.A. test is reliable, but it is essential to use a standardised technique.

Technique of Tests. Until recently there was the utmost confusion amongst creameries because different techniques were used. Thus cases have been known where bulk milk has been sent from one creamery to another and found to have (apparently) a lower acidity on arrival than when dispatched. It is obviously desirable that all creameries should be able to compare acidities. The following are the most important factors controlling the result in the laboratory :

Concentration of indicator. In titrating a colourless acid solution the amount of indicator is not important ; in milk it is of the greatest importance. Thus, if the eye can detect x units of red indicator in a colourless solution, it is probable that $20x$ or $30x$ units would be required in milk, the redness being masked by the opacity of the milk. This is illustrated in Table Ac II. In this experiment the same milk was titrated to the same visual end-point with different amounts of indicator. It will be seen that the results varied from 0·138 to 0·192 per cent. " lactic acid ", and that the *p*H end-point varied from 8·05 to 8·87. In other words, the end-point was reached in each case when a given amount of the pink form (sodium salt) had been formed. The same principle applies, of course, to all opaque liquids, including cream and whey. The opacity of whey varies enormously according to the amount of fat present. A standardised amount of indicator (1 ml. of 0·5 per cent. per 10 ml. of milk, or 2 ml. per 20 ml.) should be used for milk, cream, and whey. Table Ac II shows that it is necessary to add about 4 ml. of 0·5 per cent. indicator to 10 ml. milk to reach the constant " saturation " level. This would be scientifically ideal, but is unnecessarily high, and the dilution introduces other factors. Slight inaccuracy in measurement is unlikely to affect the result if 1 ml. is added, so that this is a satisfactory arbitrarily defined amount and is not unduly expensive in indicator. Moreover, it is a convenient volume to add.

TABLE Ac II.

Amount of Indicator (0·5 per cent.) for 10 ml. milk	*Titratable acidity (per cent.) lactic acid*	*p*H *of end-point*
1 drop	0·192	8·87
0·1 ml.	0·177	8·71
0·25 ml.	0·168	8·52
0·5	0·163	8·48
0·75	0·158	8·38
1·0	0·153	8·28
1·5	0·150	8·26
2·0	0·148	8·20
2·5	0·145	8·12
3·0	0·143	8·10
3·5	0·140	8·08
4·0	0·138	8·06
4·5	0·138	8·05
5·0	0·138	8·05

Determination of the end-point. Various aids to help in this have been proposed *viz.*:

Pink stirring rods.
Standard solutions, such as rosaniline acetate.

Using 1 ml. of indicator gives a much sharper end-point than the usual 3 drops.

Reading the burette. The usual value for fresh milk is about 0·14 per cent., so that a burette reading of 1·4 ml. is taken. The error in reading is thus rather high, considered as a percentage of the volume, *e.g.* if 0·1 ml. it is about 6 per cent. It is recommended, therefore, that 20 ml. of milk and 2 ml. indicator be used. Either an ordinary burette can be used and the result divided by 2, or a specially calibrated acidimeter (p. 5) can be obtained.

Measuring the volume of milk. If crude wide-pointed pipettes are used and no drainage time given, the volume delivered should be checked by weighing the milk. The weight of milk delivered should be 10·32 ± 0·1 g.

Carbonation of soda. Provided that the usual precaution of a soda-lime tube is employed, the small amounts of carbonate present in the soda do not significantly affect the results.

Effect of temperature. Temperature usually affects the acidity of buffers in terms of *p*H, and also affects the titratable acidity of milk on account of the effect on the dissociation of some of the acid salts. Thus it is a common observation that cooled milk may give a lower titratable acidity. It is essential, therefore, that tests should not be made on milk at very high or very low temperatures. Provided the temperature is between 55° and 75° F. (*i.e.* 18 ± 5° C.) differences will not significantly affect the result. If milks are outside this range, however, they should be brought to 18° C. by standing the bottle in water at this temperature. *See* also Cheese, p. 171.

ACIDOPHILIC. This term means acid-loving and is sometimes applied to lactobacilli which can grow at low *p*H values, *e.g. L. acidophilus.* It is doubtful, however, if this hybrid word is justified since although certain types of lactobacilli can grow at rather low *p*H values, the optimum value for growth and metabolism is much nearer the neutral point, *e.g. p*H 5 to 6. " Aciduric " is a more suitable description. *See* Lactic acid bacteria.

ACIDOPHILUS MILK. A culture of *L. acidophilus* in milk is widely used for the treatment of cases of intestinal auto-intoxication by the metabolic products of protein-splitting and putrefactive bacteria. The original culture popularised for this purpose was that of *L. bulgaricus*, but it appears that this organism cannot flourish at the low surface tensions prevailing in the intestine. Acidophilus milk has largely replaced bulgaricus milk for this purpose. It has been claimed that the same beneficial effect is produced by the drinking of an equal volume of milk or even the same amount of lactose. *See* Lactic acid bacteria.

Refs.: Burke ; Rettger *et al.* (1935), *Lactobacillus acidophilus and its Therapeutic Applications*, London ; Davis (1952), *F*, **21**, 249, 284.

" ACIDO-PROTEOLYTES ". A term applied by Gorini to those bacteria which are able to attack protein in an acid medium. They are largely responsible for ripening (protein breakdown and flavour production) of dairy products, particularly cheese. *See* Cheese ; Classification ; Lactic acid bacteria.

Refs.: Hammer ; Rogers ; Knowles (1936), *JDR*, **7**, 63 and 176 (acid-proteolytic types in rennet and milk).

ACIDURIC. *See* Acidophilic.

ACRE. 4840 sq. yds. *See* Weights and Measures.

ACTINOBACILLUS. A genus of the higher bacteria. The type species *Actinobacillus lignieresi* is responsible for actinobacillosis (resembling actinomycosis) in cattle.

Refs.: Bergey ; Wilson and Miles.

ACTINOMYCES. A genus of micro-organism between the bacteria and moulds. Type species *Actinomyces bovis.* Most species are saprophytic and may occur in soil. Colonies produce the characteristic " earthy " odour.

Refs.: Bergey ; Wilson and Miles.

ACTINOMYCOSIS. This name covers several diseases due to pathogenic *Actinomyces* but was originally given in 1877 to a disease now known as the true ray-fungus disease in cattle. The condition can also occur in man and, although rare, is very unpleasant.

Refs.: Miller ; Wilson and Miles.

ADAM'S METHOD. See Fat.

ADDED WATER. This fraudulent practice is fast dying out on account of the improvement of the freezing-point test for detecting it. It is usually suspected when the results of fat and solids-not-fat tests are low and erratic. Water can be added accidentally, *e.g.* by using a leaky cooler. The freezing-point test can detect 3 per cent. or more added water in herd bulks and 1 per cent. or more in tanker bulks (3000 gallons). Quality payment would solve the problem and dispense with the present cumbersome procedures and unsatisfactory and time-consuming prosecutions. *See* Freezing-point test; Quality payment.

ADHESION. The sticking together of two surfaces due to strong molecular attraction.

ADIABATIC. A change without gain or loss of heat. *See* Heat.

ADIPOSE. Rich in fat.

ADSORPTION. This may be loosely defined as the adhesion of matter (gas, liquid, or solid) to surfaces (liquid or solid). Scientifically, adsorption may be defined as concentration changes at an interface. The fundamental aspect of adsorption is thermodynamic, *i.e.* the concept of energy. If a solute (dissolved substance) raises the potential energy at an interface, the solute will tend to leave the interface and vice versa.

The fundamental equations are: (i) the Gibbs equation $C = \frac{-c}{RT} \cdot \frac{ds}{dc}$ where C = concentration of adsorbate on surface, c = concentration or pressure of adsorbate in vapour, s = interfacial tension, R = gas constant, T = absolute temperature; and (ii) the Freundlich adsorption isotherm $\frac{x}{m} = aC^{\frac{1}{n}}$ where x = amount of substance adsorbed by m g. of material, C = equilibrium concentration of adsorbate, and a and n are constants for any given materials.

Adsorption is of the greatest importance in dairying, particularly in relation to odours and taints (*see* Flavours), many biochemical reactions and bacteriological phenomena. *See* Detergents.

Refs.: Adam; Buchanan and Fulmer; Clayton; Rogers.

ADULTERATION. Strictly speaking this term means the addition of forbidden substances to foods, but in dairying it almost invariably refers to the addition of water to milk. It is important to bear in mind (i) when water is shown to be present it may have entered accidentally; (ii) no one can state positively that it is impossible for water to have been added unless the milk has been continuously under scrutiny from the time of leaving the cow; (iii) genuine milk can be low in solids (*see* Abnormal milk and Mastitis). *See* Freezing-point test.

Ref.: Ystgaard *et al.* (1951), *JDS*, **34**, 680, 689.

ADVANCED LACTATION. *See* Abnormal milk; Composition, factors affecting; Milk secretion.

AERATION. Applied to milk this term means the occlusion of tiny bubbles of air due to splashing, leaking glands in pumps, etc. It can lead to an error of up to 0·15 per cent. in S.N.F. when determined by specific gravity. For this reason when milk has been pumped or poured it should be allowed to stand for at least 2 hr. before the lactometer test is made. Aeration can also affect the keeping quality of milk, usually adversely. It was formerly thought correct to aerate milk in order to enhance keeping quality. This is a fallacy; aeration will help to remove odours but does not usually prolong the life of a milk.

Ref.: Davis *et al.* (1945), *DI*, **10**, 182.

AEROBACILLUS. A genus of spore-forming bacteria intermediate in character to the aerobic *Bacillus* and the anaerobic *Clostridium*.

Refs.: Bergey; Porter *et al.* (1937), *JB*, **33**, 163.

AEROBACTER. A genus name used by American bacteriologists for bacteria of the *aerogenes* group. *See* Classification; Coliforms.

AEROBES. *See* Aerobic.

AEROBIC. In the presence of air, *i.e.* oxygen. The term is used physiologically to mean in the presence of air, and bacteriologically to mean requiring air. The following table suggests terms for describing the reaction of micro-organisms to oxygen.

Reaction	*Classical Name*	*Suggested Name*
Oxygen necessary	Aerobe *or* obligate aerobe	Aerobic
Oxygen desirable	Facultative anaerobe	Aerophilic
Inert	—	Inert
Oxygen undesirable	Facultative aerobe	Aerophobic
Absence of oxygen necessary	Anaerobe *or* obligate anaerobe	Anaerobic

AEROGENES BACTERIA. *See* Coliforms.

AETIOLOGY. The study of causation, especially of diseases.

AGALACTIAE, STR. *See* Mastitis; Lactic acid bacteria; Abnormal milk.

AGAR. A carbohydrate from seaweed which forms a firm jelly at a concentration of 1·5 or 2 per cent. in water and is therefore commonly used for bacteriological media. Agar as commonly used is a polysaccharide consisting of sulphated galactosans and may vary considerably, not only in its gel-forming powers, but also in its ability to promote or inhibit the growth of certain types of micro-organisms.

AGAR STRIP METHOD. *See* Strip Method.

AGE OF COW. *See* Composition, factors affecting.

AGGLUTINATION. (i) *The Clustering of Fat Globules in Milks:* This phenomenon is caused by specific substances called *agglutinins* which may be destroyed by heat or other agents, or detached or precipitated by cold or other agents. (ii) *Of Proteins by Heat:* Proteins are first denatured and then agglutinated—probably by neutralisation of the charge on the particle. (iii) *Of Bacteria by Agglutinins:* Animals which have suffered from an infection may develop agglutinins in their blood. Such blood or serum when added to suspensions of the organism will cause it to form compact conglomerates which fall to the bottom. The smaller the concentration of blood or serum which can cause this flocculation, the higher is the " titre " or richness of the blood in agglutinins. The " agglutination test " is usually the term used by farmers, etc., for the test for the presence of *Brucella abortus*.

AGGLUTININS. (i) Proteins constituting part or all of the euglobulin fraction in milk and responsible for fat globule (*q.v.*) clustering. *See* Cream layer. (ii) The substances produced by the body in response to infection and which cause bacteria to agglutinate are called *agglutinins* and are usually globulin in nature. *See* Immunity.

Ref. : Wilson and Miles.

AGITATION. Milk in bulk is usually agitated, primarily to prevent the fat from forming a cream line and also to remove odours. Excessive agitation leads to disruption of the fat globule membrane (churning) and so to free fat, greasiness, etc. Agitation can lead to a decrease in the keeping quality of milk, probably due to the breaking up of the bacterial clusters and the effect of aeration on metabolism and growth. *See* Aeration.

Ref. : Davis *et al.* (1945), *DI*, **10**, 182.

AGITATORS. These usually take the form of propellers or paddles. A modern method is to use compressed air; crude plungers are used in some dairies. Agitators can be a dangerous source of contamination. *See* Cheese.

AGRICULTURAL EDUCATION. Institutions giving courses of instructions in Agriculture and Dairying in Great Britain.

1. Courses for B.Sc. (Dairying). Reading University; Nottingham University (at former Midland Agricultural College).

2. Courses for B.Sc. (Agriculture). Wye College, Kent; Royal Agricultural College, Cirencester (men only); Reading University; Nottingham University; Leeds University; Durham University; University College, Aberystwyth; University College, Bangor; West of Scotland College, Glasgow; East of Scotland College, Edinburgh; North of Scotland College, Aberdeen.

3. Courses for N.D.A. and N.D.D. In addition to the above: Seale Hayne College, Newton Abbot, Devon; East Anglian Institute of Agriculture, nr. Chelmsford, Essex; Harper Adams Agricultural College, Newport, Shropshire; Cheshire School of Agriculture, Reaseheath, Nantwich, Cheshire.

4. Courses leading to Certificates in Dairying. In addition to 3 above: Somerset Farm Institute, Cannington, Bridgwater, Somerset; Studley Farm Institute, Warwickshire; Lancashire Farm Institute, Hutton, Preston.

Practically all counties have their Farm Institute at which various courses of instruction can be obtained. Fuller details may be obtained from the Ministry of Agriculture, 55 Whitehall, S.W.1. *See* Research institutes.

AGRICULTURE. Introduction. Dairy farming is practised in Britain under a wide and varied range of conditions. The general agriculture of the country consists of numerous types of farming, which will be discussed in greater detail later, and dairying is carried on under most of these systems to a greater or less extent. It is impossible to lay down anything more than general lines of demarcation between one system and the next. To the west and north of the country the main farming systems are based on ley farming; grassland and small farms being a predominant feature of the area. In consequence of the plentiful supply of grass, milk production is of predominant importance except in those regions which, by reason of inaccessibility, are unsuited to the production of perishable goods.

Farther east, the Midlands area is one that is largely concerned with mixed farming, milk often taking a smaller share of the agriculture, though there are areas in the Midlands near to urban centres which produce little else but milk and dairy products. There is in this area a greater production of arable crops than in the west; not all these are for cash sale, however, some of them being used for dairy cattle feeding.

Lying on the eastern side of the country is the drier land which is predominantly arable, though dairying has made advances in recent years. Conditions in some areas favour the production of milk, particularly in the south-east where the London market is close at hand.

Generally, the main dairying areas of the country lie in those districts where grass is both cheap and plentiful, always provided the product can be sent easily to a market. High steep lands are not favoured and these are usually used for the rearing of stock, whilst the more fertile valley and sheltered lowland are used for milk production. It is worth noting that several factors have extended the distribution of dairy farms very considerably in recent years. The improvement of transport facilities has led to the sale of liquid milk from areas considered previously only as rearing areas; the decline in the profitability of beef production, particularly in yards, has led in a number of cases to the establishment of dairying in arable districts, where, although grass is scarce, the animals are fed quite profitably on arable crops. Although we have in this country a wide range of climatic and geographic types yet we have, at the same time, dairy cattle that are adapted in some measure to nearly all of them. Dairy farming is a highly important part of our farming industry yet it is practised in most areas as part of a general mixed farming system rather than as a specialist enterprise; exceptions exist primarily in the highly industrialised districts of the north where many of the farms, best suited by reason of soil, climate and aspect to rearing stock, produce milk on what is almost a factory system, buying-in most of the feeds necessary and selling their milk for retail distribution in Yorkshire and Lancashire.

Under present conditions milk is generally produced in connection with some proportion of arable farming even if that arable land is used entirely for stock-feed production. The degree of importance of the dairy herd varies very widely from those farms where it is merely a sideline, helping possibly to maintain fertility as cheaply as possible, to those where it is the focal pivot of the system. In total, however, it adds up to the most important single enterprise in the whole of our agricultural endeavour.

Farming Structure of Britain. ***Farming Systems.*** The differing farming types of this country are not defined by well-cut boundaries, having developed in response to a variety of physical and economic factors over a long period of time. They are, nevertheless, capable of some broad distinction. The system of classification adopted here is that used in the "Types of Farming" map issued by the Ministry of Agriculture. This covers only England and Wales. (Fig. Ag 1, *see also* Figs. Ag 2 and Ag 3.)

Pasture Types. (*A*) *Predominantly dairying.* This may include the production of dairying by-products and the rearing of dairy heifers as well as the main output of liquid milk. They are frequently all-grass or with the whole of the arable land devoted to stock-feed crops. This type occurs in the Cheshire plain and extends north into the industrial belt of Lancashire; the Staffordshire-Derbyshire border area, both uplands and lowlands, the Vales of Berkley, White Horse and Pewsey; the North Somerset Plain and West Dorset. Although this group is predominantly dairying, farms vary from the industrial area "flying herd" type to the cheese and buttermaking farms of Dorset, Somerset and West Cheshire.

(*B*) *Dairying plus other enterprises.* This type has encroached, owing to the war, on much of the area formerly devoted to type *A*. Under the stress of war-time demands many farms had to turn arable in some part and many have not yet reverted to their former all-grass state. Indeed, they will probably never completely go back to that state as long as agriculture is profitable and there are no supplies of cheap foreign feeds. Associated with the dairy type in this group we find nearly all other classes of farm production such as fat stock, fruit, poultry and cash crops. These are, however, subsidiary to the dairy enterprise. They are found in the Vale of Glamorgan, Upper Severn valley and Shropshire plain; Central and South Warwickshire; much of Cornwall, Devon and Somerset; the Vale of Aylesbury; South Essex and the Weald.

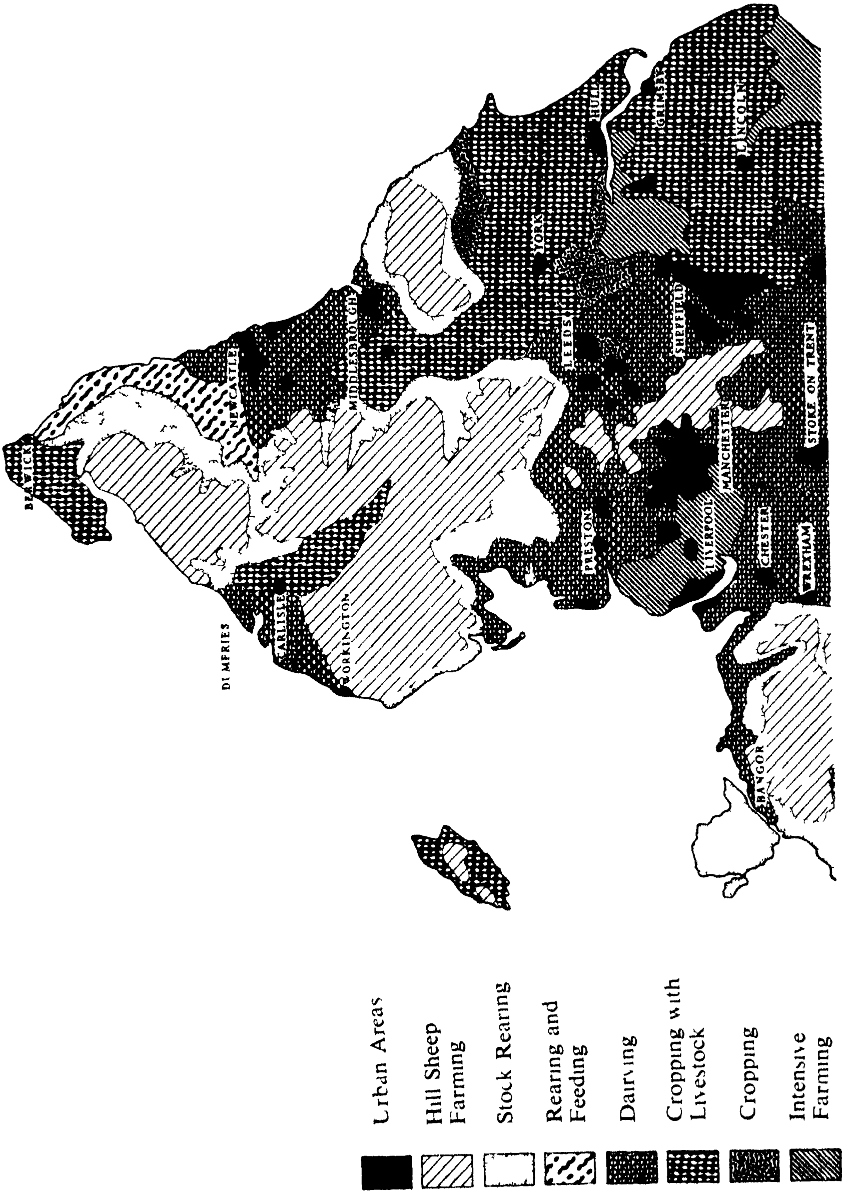
In both the foregoing types, the farms are generally small in area and many of them rely largely on the family labour.

(*C*) *Grazing and dairying.* This type is commonest in the Midlands area of Leicestershire and Northamptonshire. In recent years the amount of dairying has increased at the expense of the grazing cattle and sheep which formerly reigned supreme, due mainly to the decline in the market for fat stock. An area predominantly grassland which may retain a small amount of its war-time arable land in view of the demonstrated excellence of modern leys.

(*D*) *Rearing and other stock enterprises.* This system is mainly confined to the best of the uplands of the north and west. As well as the rearing of cattle and sheep there may be some dairying, fat stock rearing and a little arable for cash crops, depending on the quality of the land. Cattle and sheep are generally found in association on both rearing and fattening farms. The lower parts of the Pennines and the Cambrian hills together with a large area of the Devon uplands form most of this tract of farming.

(*E*) *Rearing and sheep grazing.* The less fertile parts of our uplands, together with those areas unsuited to more intensive forms of production because of poor access, are the main areas forming type *E*. These farms usually have the homestead situated in the valleys together with the cultivated lands, whilst to each farm grazing rights are apportioned for the large stretches of higher lands, probably unfenced and grazed as common land. Even so this type of farm

AGRICULTURE



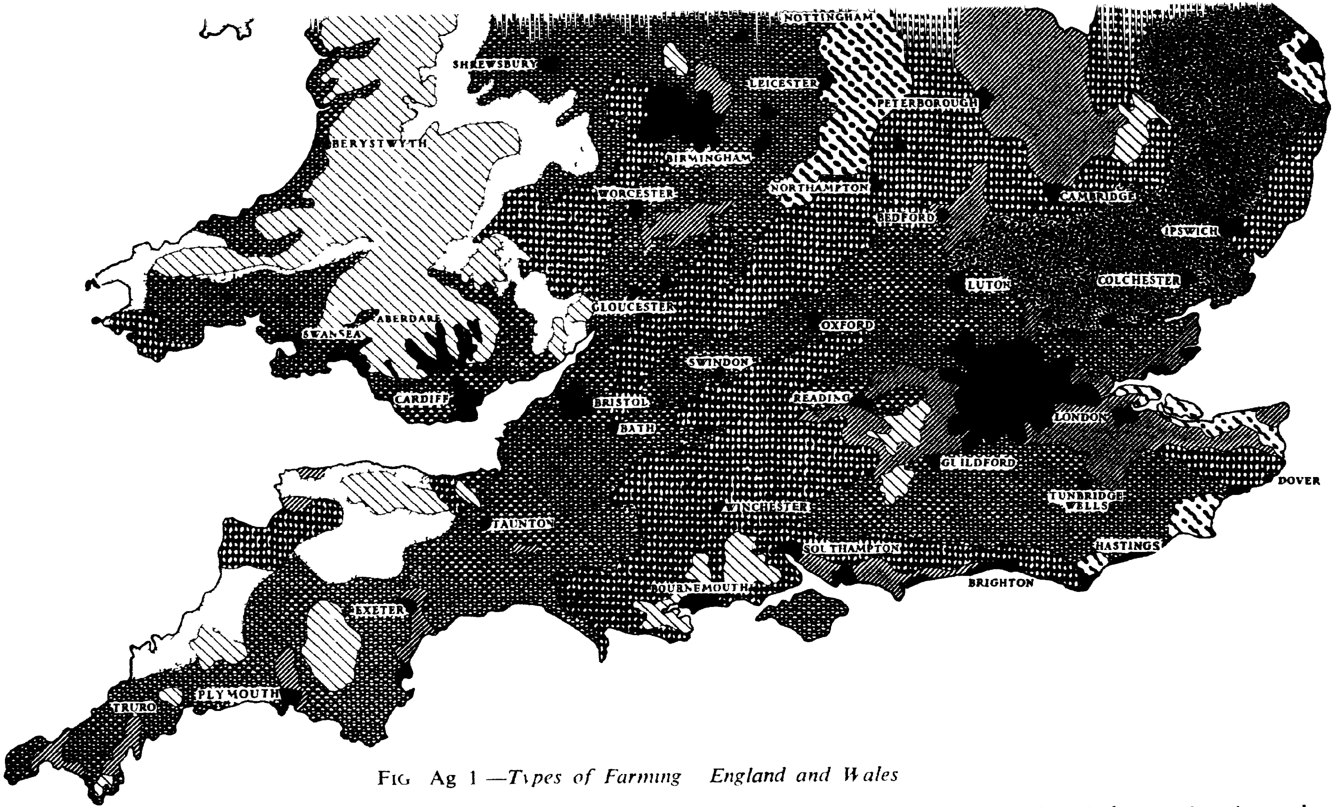


FIG Ag 1 —*Types of Farming England and Wales*

Reproduced from the map of Principal Systems of Farming in Great Britain published by Newman Neame Maps Ltd. in conjunction with the Association of Agriculture does occasionally make some contribution to the dairy market, especially since M.M.B. collection of liquid milk was extended to these remoter areas. Formerly the only dairy output was in the form of some dairy heifers and cheese or butter. Mostly these systems are typified by the Cumbrian and higher Cambrian valleys and hills. There is also a small amount of this type on the Pennine range.

Intermediate Types. (*F*) *Mixed with substantial dairying.* These are really *B* type farms with a higher proportion of land devoted to cash crops, and are usually very highly productive and with a great diversity of output. The farm system, however, pivots around the dairy. This type covers a vast area of the country, including much of the Central Midlands round Birmingham; South Devonshire; the Cumberland coast; South Yorkshire; part of the Chilterns; West Sussex and East Hampshire; and a portion round the Tyne Valley.

(*G*) *Mixed and rearing.* This system of farming is decreasing in extent owing to the fact that types *B* and *F* are more favoured by the present economic position. The Vale of Eden and Central Hereford remain to represent this type.

(*H*) *General mixed farming.* This category covers those farms where no one form of output can be distinguished as the most important. Frequently they are contributors to the milk market but equally they raise fat-stock and crops. This system is represented by farms scattered all through the country, since it is a system adaptable both to environment and to economic variations. Individually they tend to become specialists in one field of production and so change into other categories. The areas most typical of these conditions are South Durham and North Yorkshire; the limestone lands of Oxfordshire and Northamptonshire.

(*I*) *Corn, sheep and dairying.* This is the chalk land system of southern England. The relative importance of the different products depends on the markets available and the state of those markets. The war has seen the importance of sheep decline, to be replaced by dairying and corn growing. Frequently the dairy is of the bail type (see *Bail* and *Dairy farm buildings*, p. 356). Poultry and pigs are also increasingly of importance on these lands to assist in the maintenance of fertility.

(*J*) *Wheat and cattle.* The clay soils of Lincolnshire, Huntingdonshire and Bedfordshire once used to be entirely arable land. They went down to grass in the inter-war period, with wheat and cattle as the main output. The war period brought back the wheat at the expense of the cattle but already this land is reverting to its former state. Milk is produced to quite a large extent now in place of the uneconomic winter fattening of cattle.

(*K*) *Intermediate.* There are four areas of the country virtually in a class on their own. (*a*) Central Kent and part of the North Downs are a combination of types *O* and *B*. In both these areas the war has had the effect of increasing the relative importance of the dairy herds, though at the same time stimulus to the production of fruit has resulted in renewed interest in that crop.

(*b*) East Bedfordshire: In the past a dairy and cattle area but now being encroached upon by the market-garden crops.

(*c*) The Tamar valley and other market-garden areas of the West Country have ceased to be so important as mixed dairy farms.

(*d*) The area of the West Riding lying to the south and south-west of Leeds is one devoted to specialist rhubarb growing.

Arable Types. (*L*) *Mixed with arable as the focal use.* A great part of the Eastern Counties; part of the E. Riding of Yorks.; Tweedside; North-east Derbyshire; Central Sussex and North-east Herefordshire all contribute to make this group. Arable cropping forms a high proportion of the total output. Livestock are mainly fat cattle (declining), fat sheep and dairy cattle (increasing). It is an important type.

(*M*) *Corn and sheep.* This is a type that has undergone several changes even in the last decade. The difficulty of labour has meant the expansion of the system and sugar-beet, vegetables, potatoes and wheat are now important parts of the total output. Instead of the former specialist enterprise concerned with sheep and barley alone, these farms are gradually evolving a system with greater flexibility. The rotation has not changed greatly from the old standard of barley, roots and ley but the types of roots and corn have been added to. Arable flocks are still to be found in greater numbers than in the southern arable sheep areas. This type occurs mainly on the Chalk Wolds of Yorkshire and Lincolnshire; South Lincolnshire and the Sherwood area of Nottingham.

TABLE Ag I

ALL HOLDINGS OF 5 ACRES AND ABOVE

Type	*Total number of holdings*	*Total area of crops and grass*	*Proportion*		*Average size of holding*	
			By no.	*By area*	*Crops and grass*	*Rough grazings*
	000	000 acres	%	%	Acres	Acres
Pasture A	34·9	2,280	12·0	9·4	65	4
B	47·4	3,150	16·3	13·0	67	6
C	5·7	750	2·0	3·1	132	4
D	25·9	1,840	8·9	7 6	71	17
E	13·6	850	4·7	3·5	62	44
All pasture	127·5	8,870	43·9	36·6	70	12
Intermediate F	37·0	3,400	12·7	14·0	92	6
G	8·7	750	3·0	3·1	86	6
H	8·1	990	2·8	4·1	122	3
I	6·4	1,110	2·2	4·6	173	30
J	4·1	530	1·4	2·2	129	17
K	2·9	170	1·0	0·7	59	3
All intermediate	67·2	6,950	23·1	28·7	103	7
Arable L	13·6	1,450	4·7	6·0	106	3
M	3·8	650	1·3	2·7	172	5
N	6·7	940	2·3	3·9	140	7
O	16·3	1,210	5·6	5·0	74	1
P	5·2	360	1·8	1·5	69	2
Q	4·7	600	1·6	2·5	128	1
All arable	50·3	5,210	17·3	21·6	104	3
Miscellaneous X	9·0	560	3·1	2·3	62	90
Y	1·7	170	0·6	0·7	100	4
Z	34·9	2,440	12·0	10·1	70	30
England and Wales	290·6	24,200	100·0	100·0	83	14

(*N*) *Corn, sheep and cash crops.* It might be said that most of type *M* is changing to this system whereby cash crops such as sugar-beet and potatoes form an important part of the rotation. Some of these lands near to markets have taken to vegetable crops also. They occur in East Suffolk; South Cambridgeshire; North and West Norfolk; North Lincolnshire and the Pocklington area of Yorkshire.

(*O*) *Cash cropping.* The Fen country of East Anglia is the main area, others being those in the region of Liverpool; South Yorkshire; North and Central Kent. Fertile land with intensive farming, where high output per acre is necessary to be economic. Little livestock except for fertility maintenance. Wheat, sugar-beet, potatoes, vegetables and fruit are the main crops.

TABLE Ag II

LAND CLASSIFICATION

Category of land	*England and Wales*		*Scotland*		*Great Britain*	
	Acres	*Surface* %	*Acres*	*Surface* %	*Acres*	*Surface* %
1. **Good**	17,846,300	47.9	3,546,700	17.5	21,393,000	37.9
(*a*) .	1,962,900	5.3	368,100	1.9	2,331,000	4.1
(*b*) (i) .	7,065,800	19.0	1,500,800	7.7	8,566,600	15.2
(*b*) (ii) .	2,636,700	7.1	211,000	1.2	2,847,700	5.0
(*c*) .	1,235,200	3.3	7,600	0.0	1,242,800	2.2
(*d*) .	4,945,700	13.3	1,459,200	7.7	6,404,900	11.4
2. **Medium**.	11,933,700	32.0	1,910,800	10.1	13,844,500	24.6
(*a*) (i) .	2,402,200	6.4	84,600	0.5	2,486,800	4.4
(ii) .	220,300	0.6	1,000	0.0	221,300	0.4
(*b*) .	9,311,200	25.0	1,825,200	9.6	11,136,400	19.8
3. **Poor** .	6,350,400	17.0	13,493,100	70.8	19,843,500	35.2
(*a*) .	825,500	2.2	75,400	0.4	900,900	1.6
(*b*) .	4,516,500	12.1	13,371,300	70.1	17,887,800	31.7
(*c*) .	811,300	2.2	46,400	0.3	857,700	1.5
(*d*)	197,100	0.5	—	-	197,100	0.4
4. **Residue** .	1,141,900	3.1	118,800	0.6	1,260,700	2.3

(*P*) *Market gardening.* Bedfordshire; Vale of Evesham; Wisbech; part of Cambridgeshire and West Huntingdonshire; the Botley area of Hampshire and much of the land to the east and west of London are all concerned in the production of crops for direct human consumption. The land is generally of good fertility with good access to markets. The fertility is maintained by stock, especially pigs, but also including some dairy stock.

(*Q*) *Other arable types.* (*a*) The clay lands of East Yorkshire; the Suffolk-Essex border and the West Cambridgeshire-East Huntingdonshire areas are all lands which are both heavy and fertile. They are largely used for arable crops, especially wheat which forms up to 33 per cent. of the rotation.

(*b*) The North Cheshire plain is unique in type and concentrates on milk, potatoes and wheat.

(*X*). (*Y*) and (*Z*). *Lands of little agricultural value, marshlands or unclassified.* The *X* type lands are those that are inaccessible, such as the mountains and fells in the north and west, miscellaneous heathlands and lands under afforestation. *Y* type are the marshes nearly all along the coasts though a few are inland. There is rough grazing, though some are very valuable as is the Romney Marsh. *Z* lands are unclassifiable areas where all types are so mixed that the pattern of farming is highly irregular. The Hampshire basin and the mid-Thames valley; much of Surrey; part of the North Downs and the Chagford area of Devon.

The pressure of urban demand also plays a part in creating such a varied farming system.

It will be seen then that the vast majority of our farming systems make some contribution to the dairy industry, either by supplying milk and milk products or by rearing dairy stock. Only the lands that are virtually inaccessible and those of the highest fertility are outside the dairy industry. With the decline of the fat-stock market, particularly for cattle, the relative importance of the dairy cow has increased.

Table Ag I gives the total number, cultivated area and average size of holdings for each type of farming.

Table Ag II shows the quality of our land as classified by the Land Utilisation Survey completed just before the war. In respect therefore of built-over land this underestimates the figure—*see* Marginal and Waste Lands.

Classes in the above table:

Good: (*a*) First class.
- (*b*) (i) Good general purpose, suitable for ploughing.
  - (ii) Good general purpose—crops or grass.
- (*c*) First class, restricted use, unsuitable for ploughing.
- (*d*) Good but heavy land.

Medium: (*a*) Medium light land:
  - (i) Suitable for ploughing.
  - (ii) Unsuitable for ploughing.
- (*b*) Medium general purpose farmland.

Poor: (*a*) Poor heavy land.
- (*b*) Poor mountain and moorland.
- (*c*) Poor light land—heaths.
- (*d*) Poorest land.

Residue: Closely built over—urban uses.

The location of these farming systems is affected by various physical and economic factors:

Physical. Climatic influences, such as rainfall, temperature and sunshine exert some control over the system to be followed in any one area. Of these, rainfall is the most important. It is largely because of this factor that our main pasture lands are to be found in the west and north whilst the arable lands lie mainly to the east. Intermediate types tend to exist in the belt of land lying between the two, running from the Tees to the Exe and broadening out in the Midlands area. During the war there was a tendency for the arable and intermediate types to spread westwards, even though dairy stock at the same time was increasing in numbers. Grass tends to favour the wetter parts of the country, while for growing and harvesting arable crops a lower rainfall is preferable. The west of the country is also rather warmer than the east, and this favours the growth of early spring grass. Elevation is another of the physical factors which, apart from its effect on climate, especially in the hill regions, renders the lands of the north and west less suitable for ploughing and arable cropping. Other factors such as soil type and fertility also influence the choice of system. In addition to these, *economic* factors, such as access to markets and profitability, are of importance. Other things being equal, the nearer to the consuming centre the more intensive the production: perishable products must be marketed rapidly and easily. Though the greater part of our liquid milk industry used to be centred round the urban areas, modern transport has now created a pattern with strips of intensively producing farms along all our roads and railways, on which the goods can be carried easily and quickly to the market centres. The distribution of arable land is less affected by market access, since the farm products have not to be marketed so frequently; only in the case of market-gardening and soft fruits is the market question so important, as it is in dairying. Areas unsuited by reason of soil or position to either dairy or arable farming, tend to follow a system which will supply either the needs of the dairy and arable farmers for stock replacements, or the fat-stock for the consumer market.

Changes in the farming systems of this country have been accelerated by the war; some increase has occurred in temporary grasslands and is likely to remain. The increase in the arable acreage of the western half of the land is also expected to remain. There has been a reduction in the need for hand labour by changes in crops and increasing mechanisation. A factor which may cause some reversion in the future is the possibility of foreign competition once more; stock farming will increase and arable will decrease, though it is likely that even then the reversion will never be as great as it was pre-war.

Size of Holdings and Type of Occupiers. Table Ag III gives data concerning all holdings over one acre, collected each year by the Ministry of Agriculture. Since many of those in the 1 to 5 acres group are not bona fide agricultural holdings, they need not be considered in determining the " average ". In all the changes that have been wrought on the land in the past half-century, the size of the holdings has remained relatively stable.

TABLE Ag III

NUMBER OF HOLDINGS BY SIZE GROUPS (1885–1945)

Year	5–20	20–50	50–100	100–300	*Over* 300	*Average size*
England and Wales						
1885	126,647	73,472	54,937	67,024	16,608	61·1
1895	126,714	74,846	56,791	68,277	16,021	62·9
1913	122,117	78,027	59,287	69,431	14,513	62·3
1921	116,159	80,967	61,001	67,842	12,947	62·3
1931	102,339	77,374	61,951	66,927	12,146	64·5
1938	90,990	72,946	61,685	66,100	11,827	67·5
1945	88,163	68,480	60,274	62,259	12,360	--
Scotland						
1895	33,921		22,802		2,766	64·0
1913	33,196		10,047	13,106	2,621	62·0
1921	32,923		10,145	13,050	2,511	62·2
1931	33,717		10,244	12,722	2,389	61·1
1938	32,654		10,030	12,586	2,368	61·6

These statistics, although they show the changes in the number and size of holdings, do not give any information as to changes in actual farm boundaries. The first comprehensive boundary maps were prepared by the National Farm Survey in 1941; the only available evidence for comparison is the survey made by the Tithe Commutation Commission in 1851. The comparison tends to show that in some areas a slow but steady consolidation of farm units and a reduction in scattering has taken place over the past century, though in others which have become important as market-garden lands the reverse has occurred. A pilot survey conducted in 1943 over some 24 square miles of central England showed that 27 per cent. of the farms were in two or more blocks, and of 133 farms only 62 could be classed as convenient to work from the point of view of layout.

The types of holdings in this country are generally considered on the basis of their occupiers, size or enterprise. The farm survey referred to above (National Survey 1941) showed that on holdings over 5 acres there are 215,900 farmers farming full-time on 21,296,000 acres of crops and grass, giving the average farm size as one of 99 acres. If the 5½ million acres of rough grazings in England and Wales are about equal to half a million acres of good land then the average farm is one of 101 acres. As the average rural family nowadays is 3·15 persons this gives a farmer population of about 20 to the square mile (640 acres). Adding workers in agriculture and others in secondary occupations, the total rural population is about 100 to 120 to the square mile, children of school age forming 17 per cent. of this figure. In 1871 the corresponding totals were 180–200 to the square mile with 24 per cent. school children. This is only one of the problems facing those responsible for village planning and schools. Thus, although our farms are much the same size now as they were 65 years ago, they no longer support such a large rural population. Increases in efficiency and changes in systems have both led to this.

TABLE Ag IV

Classification of Occupiers by Economic Type. England and Wales (1941)

Type of occupier	By number		By area	
	Number 000	*Per cent.*	*Acres crops and grass 000*	*Per cent.*
Full-time . . .	215·9	74·3	21,296	88·0
Part-time . . .	32·5	11·2	1,379	5·7
Spare-time—				
(i) Regular . .	25·6	8·8	460	1·9
(ii) Occasional . .	2·9	1·0	315	1·3
Hobby . . .	7·6	2·6	315	1·3
Other	6·1	2·1	435	1·8
Total	290·6	100·0	24,200	100·0

Holdings may be classified according to the economic type of the occupier. In the *Farm Survey* of 1941 a five-group classification was used (Table Ag IV):

(*a*) *Full-time.* This category includes market-gardeners, poultrymen, and horticulturists. Anyone fully engaged in farming and wholly dependent on it for his living, falls into this class. Few of these men occupy less than 25 acres unless they are intensive producers.

(*b*) *Part-time.* "Occupiers" in this class have some other occupation besides farming though still largely dependent on the latter for their main livelihood. The secondary occupation may be connected with farming, as machinery contracting, dealing and corn selling, or entirely separate, as shop-keeping. Generally these holdings are smaller in size than the full-time holdings, since only part of the day is available for work on the land.

(*c*) *Spare-time.* The spare-time holder runs his holding as a secondary employment to some other full or nearly full-time work. His holding forms a supplement to his income. This class can be subdivided into (*a*) those who run a holding regularly either with or without the help of family labour. Normally a few acres in extent and devoted to market-garden crops and small livestock. Often devoid of house or buildings. Run by working men of small means. (*b*) Those whose work only permits them to devote occasional periods to the holding and who therefore have a manager or bailiff to do the detailed running. These may be quite large holdings as there is usually capital available.

(*d*) *Hobby*. The hobby farmer is an occupier who farms for pleasure rather than for profit; *i.e.* he is independent of his holding for a living. He will naturally hope and endeavour to achieve a profit. He may hold the land because it is attached to a residence that he wants, or he may regard the farm as an interesting main occupation though not necessary to his living.

(*e*) *Other*. Includes occupiers of the home farms of estates; those who possess accommodation land used in connection with their main trade, being something other than farming; farms run by schools, colleges, executive committees, Crown Commissioners, etc.

The above table, taken from the 1941 *Farm Survey* shows the numbers of self-contained holdings; since some occupiers may actually possess more than one, the number of individuals is rather exaggerated. Information on this question of dual occupancy is given as follows:

Single occupancies	267,000
Two or more occupancies . . .	10,000 approx.
Total self-contained units . . .	290,600.

Therefore there are some 277 thousand occupiers with 290·6 thousand holdings. It should also be realised that the exclusion of holdings below 5 acres has the effect of reducing the number of regular spare-time and accommodation holders to a greater extent than those of the other types.

85·5 per cent. of the total occupiers, farming 93·7 per cent. of the land are wholly or mainly dependent on their farms for a living. Further, over 95 per cent. of the occupiers are farming for business or profit motives. Small farms appear to be the rule in the regular spare-time class with nearly 9 per cent. of the occupiers on less than 2 per cent. of the land. Table Ag V shows this fact quite clearly:

TABLE Ag V

RELATIONSHIP OF SIZE TO ECONOMIC TYPE

Type of occupier	*Size group (acres of crops and grass)*					*All holdings over 5 acres*	*Average size of holding*
	5 *to* 25	25 *to* 100	100 *to* 300	300 *to* 700	700 *and over*		
	%	%	%	%	%	%	acres
Full-time .	47·6	85·8	92·5	89·5	83·4	74·3	99
Part-time .	19·6	8·7	3·9	4·2	4·5	11·2	43
Spare-time							
(i) .	22·1	2·8	0·6	0·6	0·4	8·8	18
(ii) .	1·2	0·7	0·9	1·7	4·2	1·0	109
Hobby .	5·5	1·0	0·9	1·3	2·0	2·6	41
Other .	4·0	1·0	1·2	2·7	5·5	2·1	72
All . .	100·0	100·0	100·0	100·0	100·0	100·0	84
Number of holdings 000	101·4	111·4	65·2	11·2	1·4	290·6	—

Nearly half the occupiers of holdings under 25 acres are dependent on their farms for a livelihood, suggesting that they are mainly intensive and specialist producers; they form 23 per cent. of the full-time farmers of the country. The slight drop in the number of full-time farmers in the high acreage group is due to the number of large farms occupied by professional and business men and by educational establishments.

Since these figures relate to the whole of England and Wales there is no indication of the distribution of the differing types in each district. Regular spare-time farmers form a higher percentage of the total occupiers in Wales than they do in England, being 14 per cent. in the former and only 8 per cent. in the latter. Some counties have up to 15 per cent. in both England and Wales, being mainly those of industrial areas. As the survey excludes most of these occupiers, however, the figures are not accurate. The occasional spare-time farmer and the hobby farmer are both mainly in the south-east of the country within easy reach of London. Hobby farmers reach 10 per cent. of the total in some of the Home Counties.

For classification according to farming types, *see* section on *Farming Systems*, p. 15.

Data for the distribution of types of occupiers, the sizes of holdings and the numbers of cows on holdings in relation to the types of farms are given in Tables Ag VI, VII and VIII.

TABLE Ag VI

RELATION OF OCCUPIER TYPE TO FARMING TYPE (ENGLAND AND WALES)
(Farming types as classified under Farming Systems)

Type of farming	*Proportion of occupiers*					
	Full time	*Part time*	*Spare time* (i)	*Spare time* (ii)	*Hobby*	*Other*
Pasture	%	%	%	%	%	%
A	73	12	10	1	2	2
B	74	11	10	1	2	2
C	74	12	8	1	3	2
D	74	12	11	—	2	1
E	76	8	13	—	2	1
Intermediate						
F	72	10	9	2	4	3
G	74	12	8	1	4	1
H	74	11	8	1	4	2
I	69	12	7	2	6	4
J	75	12	10	1	1	1
K	73	15	4	—	5	3
Arable						
L	77	13	4	1	2	3
M	74	11	7	2	3	3
N	74	13	6	2	2	3
O	84	11	3	—	1	1
P	80	12	3	1	1	3
Q. i. Dairy	86	8	2		—	4
Q. ii. Heavy land	77	12	5	1	2	3
Miscellaneous						
X	73	11	11	—	2	3
Y	69	18	7	1	2	3
Z	74	10	10	1	3	2

TABLE Ag VII

DISTRIBUTION OF HOLDING BY SIZE AND FARMING TYPES

Type of farming	*Size of holding (acres of crops and grass)*				
	5–25	25–100	100–300	300–700	700 *and over*
	Number of holdings				
Pasture					
A	12,800	14,700	6,780	580	40
B	17,300	19,940	9,240	870	50
C	1,100	2,000	2,050	500	50
D	9,350	10,300	5,590	610	50
E	4,600	6,400	2,500	100	—
Pasture	45,150	53,340	26,160	2,660	190
Intermediate					
F	12,000	12,640	10,640	1,600	120
G	2,650	3,150	2,600	290	10
H	2,350	2,150	2,890	640	70
I	1,950	1,800	1,550	850	250
J	1,150	1,250	1,250	400	50
K	1,300	1,100	400	100	—
Intermediate	21,400	22,090	19,330	3,880	500
Arable					
L	4,200	4,650	3,740	910	100
M	1,050	860	1,190	600	100
N	2,050	2,050	1,680	720	200
O	6,100	6,600	2,990	530	80
P	2,800	1,300	830	240	30
Q. i	300	400	200	—	
Q. ii	850	1,200	1,300	400	50
Arable .	17,350	17,060	11,930	3,400	560
Miscellaneous					
X	3,250	4,330	1,250	140	30
Y	600	590	400	100	10
Z	13,700	13,950	6,140	970	140
All groups .	101,450	111,360	65,210	11,150	1,430
Total area 000 acres .	1,230 (5 %)	6,120 (25 %)	10,770 (45 %)	4,600 (19 %)	1,480 (6 %)

Together with Table Ag I (*q.v.*) Table Ag VIII shows the number of farms in each area which provide the farmer with a main occupation and source of livelihood.

The predominance of dairying is clearly shown. Note the incidence of cows even on arable farms.

Our Farm Lands. ***Rotations.*** Rotations for dairy farms and mixed farm where stock is the main enterprise are nearly always based on the needs of the stock both for summer and winter food. The summer feeding is customarily

TABLE Ag VIII

RELATION OF FARMING TYPE TO COWS ON HOLDING

Type of farming	None	1 to 3	4 to 9	10 to 19	20 to 29	30 to 49	50 to 69	70 to 99	100 and over
	Number of cows								
	percentage distribution of holdings								
Pasture									
A	13.3	13.4	17.1	24.9	13.2	12.3	3.9	1.5	0.4
B	13.5	19.3	28.1	24.0	8.5	5.1	1.0	0.4	0.1
C	14.2	21.3	24.0	23.5	9.5	5.8	1.3	0.2	0.2
D	11.7	25.8	37.2	18.4	4.4	1.8	0.4	0.1	0.2
E	7.5	26.4	40.6	20.0	4.0	1.2	0.2	0.1	0.0
Intermediate									
F	21.5	17.0	21.2	21.2	9.4	7.2	1.7	0.6	0.2
G	16.3	25.3	31.7	18.0	5.7	2.4	0.4	0.2	0.0
H	20.3	24.9	25.6	17.7	6.6	3.8	0.6	0.3	0.2
I	23.7	17.9	19.2	14.8	8.9	8.8	3.6	1.7	1.4
J	20.4	24.1	31.5	16.3	4.5	1.9	1.1	0.1	0.1
K	40.8	13.5	17.0	18.4	5.1	3.8	1.0	0.4	0.0
Arable									
L	37.8	23.3	18.1	9.9	4.6	4.3	1.1	0.5	0.4
M	22.7	29.8	27.0	11.8	4.2	3.3	0.7	0.3	0.2
N	37.5	26.2	18.4	9.5	4.7	2.3	0.9	0.3	0.2
O	47.2	29.0	14.3	7.3	1.1	0.8	0.2	0.1	0.0
P	69.3	10.6	8.1	6.2	2.2	2.1	0.7	0.6	0.2
Q i	11.3	20.1	16.6	21.1	15.6	12.5	1.8	0.4	0.6
Q ii	29.2	27.7	24.4	11.8	3.3	2.6	0.8	0.1	0.1
Miscellaneous									
X	13.8	25.1	35.6	18.5	4.8	1.7	0.3	0.1	0.1
Y	40.0	23.6	17.8	9.6	5.2	2.4	1.1	0.2	0.1
Z	22.2	21.4	26.3	17.8	6.5	4.2	0.9	0.4	0.3
England and Wales	21.0	21.0	25.2	18.7	7.1	5.0	1.3	0.5	0.2

grass, either of a permanent or temporary nature, though other crops such as lucerne and maize may be fed during the summer period. Normally these latter semi-arable crops are grown mostly in the Eastern Counties though they are spreading farther afield as their value becomes more apparent. In the main, however, the pasture is the mainstay of the summer period. Winter feed is supplied either by crops actually growing in the winter or by feeds preserved during the summer and stored for winter use. Kale, swedes, rye, rape, and sugar-beet tops all fall into the first of the two categories, whilst hay, straw, and cereals form with silage and dried grass the bulk of the preserved foods. The rotation on this class of farm has, therefore, to provide grass, both for grazing and for preservation in the form of hay, silage or dried grass, green foods for autumn and spring grazing or feeding and cereals, probably with legumes, for concentrated winter feed.

Under the modern conception of grassland most of our pastures are now incorporated into the rotation and ploughed up, cropped and re-seeded every

TABLE Ag IX

Cropping of Farms

Type of farming	*Cropping (percentage of crops and grass)*									
	Wheat barley rye	*Other cereals*	*Potatoes and sugar beet*	*Fodder crops*	*Hops and orchards*	*Small fruit and vegetables*	*Bare fallow*	*Temporary grass*	*Permanent grass*	*All crops and grass*
	%	%	%	%	%	%	%	%	%	%
Pasture										
A	5·6	9·9	1·3	3·1	0·8	0·3	0·3	3·1	75·6	100
B	7·8	14·0	1·8	3·5	0·9	0·6	0·4	6·4	64·6	100
C	10·7	12·6	1·1	3·1	0·1	0·2	1·4	2·8	68·0	100
D	6·0	15·8	1·3	4·4	0·3	0·2	0·1	10·3	61·6	100
E	3·0	14·6	1·2	3·9	0·1	0·1	0·1	8·2	68·8	100
Pasture .	6·6	13·3	1·5	3·6	0·6	0·4	0·4	6·2	67·4	100
Intermediate										
F	13·3	14·8	3·8	5·1	1·0	0·9	0·8	8·4	51·9	100
G	9·9	14·7	2·9	5·0	4·1	0·4	0·1	10·2	52·7	100
H	20·0	13·3	3·4	5·9	0·1	0·9	1·5	7·5	47·4	100
I	21·7	14·7	1·6	7·4	0·6	0·3	2·4	9·1	42·2	100
J	23·8	10·3	5·2	5·5	0·2	2·0	3·2	6·6	43·2	100
K	10·1	11·5	5·0	5·4	5·2	6·3	0·9	5·9	49·7	100
Intermediate	16·0	14·1	3·4	5·6	1·2	0·8	1·3	8·4	49·2	100
Arable										
L	31·9	13·7	7·4	8·1	0·6	2·0	1·0	9·1	26·2	100
M	28·2	11·3	3·5	12·4	0·3	1·8	1·1	11·4	30·0	100
N	31·8	11·0	12·0	9·4	0·3	3·4	0·9	8·0	23·2	100
O	23·5	13·7	24·5	4·1	0·6	6·2	0·5	6·1	20·8	100
P	17·3	9·6	8·1	5·1	14·2	12·3	1·4	3·3	28·7	100
Q. i	9·8	22·5	11·7	3·2	0·2	0·3	0·0	23·2	29·1	100
Q. ii	35·0	15·3	3·8	6·2	0·3	1·8	3·2	9·2	25·2	100
Arable .	28·4	12·9	11·5	7·5	1·4	3·9	1·1	8·3	25·0	100
Miscellaneous										
X	4·4	7·7	1·6	3·8	0·1	0·5	0·2	3·7	78·0	100
Y	15·3	8·2	4·2	4·9	1·7	3·6	1·8	3·7	56·6	100
Z	11·0	13·1	3·4	5·3	0·7	1·7	0·7	7·0	67·1	100

few years. It is not possible to lay down a uniform rotation as each case has to be fitted to the individual needs. The majority of our farms include at least one cash crop in the rotation and possibly two. The farm may run two rotations; one for the pasture land, say five years ley, two years crops and five years ley; and one for the arable land to include possibly one year leys for hay, silage or drying; *viz* wheat; mixed corn; potatoes; sugar beet, oats, ley

Cropping and stocking. Tables Ag IX and X show the cropping and stocking for the farms of England and Wales according to types of farming.

TABLE Ag X

STOCKING OF FARMS

Type of farming	*Livestock per 100 acres crops and grass*						*Whole-time workers per 100 acres*
	Total cows	*All other*	*Total sheep*	*Total pigs*	*Total poultry*	*Working horses*	
Pasture							
A	24.5	19.1	26.4	8.9	229.2	2.6	1.9
B	15.3	22.2	45.7	7.8	159.2	2.6	1.7
C	8.0	23.7	70.2	2.5	78.5	1.3	1.2
D	10.3	22.4	105.9	4.7	136.2	2.3	1.3
E	11.4	21.1	181.6	2.1	134.9	2.7	1.2
Pasture	15.6	21.5	68.3	6.4	163.3	2.4	1.6
Intermediate							
F	12.2	18.0	37.5	6.6	142.5	2.2	1.9
G	8.9	22.2	75.4	5.5	142.3	2.4	1.7
H	6.6	18.0	45.1	5.4	113.5	2.1	1.6
I	9.0	12.0	46.2	6.2	85.1	1.3	1.8
J	5.4	15.4	32.8	4.5	101.3	1.9	1.5
K	12.0	15.0	31.9	17.2	177.8	2.5	3.8
Intermediate	10.0	17.2	43.6	6.3	126.9	2.0	1.8
Arable							
L	6.6	11.4	19.3	11.0	174.2	2.5	2.9
M	4.0	10.4	61.5	5.5	87.4	1.8	1.6
N	4.1	9.6	28.6	8.0	107.5	2.1	2.6
O	3.9	9.6	8.5	8.1	147.3	3.6	3.6
P	5.4	8.8	41.3	12.4	137.0	2.0	5.6
Q i	21.2	12.3	7.5	7.0	166.0	3.2	2.5
Q ii	4.2	9.7	28.4	9.9	110.4	2.1	2.0
Arable	5.1	10.2	26.0	9.0	135.9	2.5	2.9
Miscellaneous							
X	11.5	17.7	268.3	4.2	238.0	2.4	1.5
Y	6.1	15.4	110.4	3.9	99.1	1.6	2.2
Z	12.3	17.8	97.0	7.9	167.5	2.5	2.2

As far as cropping is concerned, the overwhelming predominance of grass and grassland systems must be noted, although it is important to remember that the figures relate to 1941 and changes have occurred since then, the relative difference between the types of farming will have changed little if at all. Of our holdings over 5 acres, 44 per cent. are predominantly pasture and occupy 37 per cent. of the land. In view of the fact that dairying is the most substantial enterprise on 45 per cent. of our land holdings, and that it is mainly a grassland system, it can be seen that grass is our most important single crop (see Table Ag I). The varying importance of other crops can be seen from the *Agricultural Returns* (p. 45) which show over the last decade the changes in emphasis due to the war-time drive for self-sufficiency.

The relative importance of the various classes of stock in each class of farming is shown in Table Ag X. This is likely to be an underestimate as regards the cattle figures, and probably also the poultry figures, whilst the numbers of sheep and horses have almost certainly declined from these. Some idea of the changes may be obtained from the *Agricultural Returns.* However, the indications of system difference still hold good. The dairy farms have, naturally, the greatest number of cows per 100 acres but also carry fair stocks of other livestock, particularly poultry which are becoming increasingly important on the dairy farm. Pigs appear to be most important in association with fruit and market-garden crops although nearly all arable types carry more than the rest. Sheep are, of course, the predominant animals in Group *E* but they are also of very substantial value in groups *C*, *D*, *G* and *M*. On the miscellaneous lands sheep are of some merit, since much of these lands are incapable of supporting anything else. The very high figure for poultry on *X* lands appears to be associated with the large area of rough grazings per holding.

Table Ag VIII shows the supreme importance of dairying in this country. Types *A* and *Q* have well over 50 per cent. of their holdings with 10 or more cows. All the pasture and intermediate types have at least a quarter with more than 10. Type *I* is the system of the larger herds and " bail " dairying, which needs a fairly large herd to make it economic to run. Arable farms with the exception of arable-dairying have fewer cows though even then over 10 per cent. have more than 10 cows. Of all our farms only 21 per cent. are without cows and 33 per cent. have more than 10 each.

Grassland. Forming over 40 per cent. of our cultivated land, grass is our most important single crop (Table Ag XI). Since statistics were first officially collected in 1866, a distinction has been made between " Permanent " and " Rotation or Temporary " grass. Later, division of these two sections into grasses " for hay " and " not for hay " was added. The actual distinction of one from the other is not so easy but, in general, leys of over three years' duration are considered as " Permanent " grass. From the Ministry returns we find that the proportion of temporary grasses has increased, particularly during the last decade. For this improvement Sir R. G. Stapledon is largely responsible.

TABLE Ag XI

GRASSLAND IN GREAT BRITAIN AND NORTHERN IRELAND

(in 000 acres)

	Permanent		*Rotation*	
Year	*For hay*	*For grazing*	*For hay*	*For grazing*
1939	5,009	13,764	1,902	2,191
1942	3,533	10,173	2,102	1,729
1944	2,613	9,122	2,491	2,234
1946	2,607	9,410	2,905	2,779
1947	2,899	9,504	2,963	2,687
1948	2,961	9,436	2,723	2,760
1949	2,936	9,743	2,932	2,788

Although the amount of permanent grass has increased again since the end of the war, there is no sign that it will regain its former acreage. It is perhaps some indication of the value of temporary grasses that there are now over 1,000,000 acres less grass devoted to hay for mowing than there were pre-war. It is true that horses and sheep are less in numbers, but cattle have increased considerably. The increasing use of leys means a higher standard of pasture management since the temporary grass is more sensitive to either bad or good treatment than the permanent pasture. The ley systems of farming have always been a feature of the agriculture of the wetter parts of the country where any pasture is found to deteriorate faster than in the areas of low rainfall. Detailed studies of the grassland of this country as regards type, distribution and ecology have been described by Sir R. G. Stapledon and Wm. Davies in *Ley Farming* and by the Land Utilisation survey of 1930–38. The survey conducted by Stapledon and Davies in 1938-40 covered only England and Wales. They calculated that only 1·6 per cent. of our permanent pasture was of the first grade, 5·8 per cent. second grade, 27·4 per cent. third grade, 60·6 per cent. fourth grade, and 4·6 per cent. fifth grade, a truly undesirable state of affairs. The Land Utilisation work covered Scotland as well on the same basis.

Marginal and Waste Lands. The exact definition of marginal land is not easy. For the purposes of this article, all land falling into the categories of moors, mountains, heaths, deer forest, saltings and " agriculturally unavailable " is included (Table Ag XII).

Table Ag XII

Extent of Marginal and Waste Lands (Great Britain)

Land Utilisation Survey (see also Table Ag II)

Type of land	*Extent*	*% of total land*
	000 acres	
Heathland, moorland and rough grazing . . .	18,775	33·0
Forest and woodlands—		
High forest	1,610	3·0
Coppice	537	1·0
Uneconomic	1,072	2·0
Houses with gardens; allotments	1,720	3·0
Land agriculturally unproductive, including airfields, etc.	1,399	2·5
Total	25,113	44·5

The information from the Ministry about rough grazings shows that from 1939 to 1946 the area increased from 16,539,000 to 17,228,000 acres, which increase largely means an increase in the land utilised and not a regression of our crop and grassland.

About 70 per cent. of the land in Scotland and 17 per cent. in England and Wales can be classified as marginal; this is the problem land of the country, since much is reclaimable and many areas do show traces of past cultivation. Its potential use depends on the soil, position, and climate. Waste lands—including those used for quarries, mining tips, gravel pits, service training as well as urban areas and sports grounds—amount to a further 3,120,000 acres or 5½ per cent. of our land in Great Britain. The pre-war annual rate of loss of farmland for these purposes was about 60,000 acres and tending to increase. The war brought immense demands by the services and some 1,000,000 more acres were lost to farming. Other war-time demands also took a quota.

Although some of this land has reverted to agriculture, much is permanently lost and indeed the rehousing of our rising population will probably result in some 10 per cent of our land being scheduled in the waste or derelict category.

Much reclamation work was done during the war and the acreages of rough moors and heaths are overstated by this amount Some 45 to 50 per cent. of our total land is at present being used agriculturally solely for the grazing of sheep and cattle on an extensive scale, or for the growing of forests

Self-sufficiency. Pre-war Britain was about 40 per cent self-sufficient in calories though nearly 50 per cent in retail value, due to the specialisation of home agriculture on the higher priced animal products. Only in the case of milk and potatoes were we 100 per cent independent of imports, though even here 25 per cent of our milk output depended on imported feeding-stuffs

TABLE Ag XIII

SUMMARY TABLE OF CROP AND GRASS INCREASES, 1939 49

(See statistics, p 45 for full table)

In 000 acres	1939	1943	1945	1946	1948	1949
Arable	12,906	18,728	19,183	18,994	18,663	18,382
Permanent grass	18,773	12,330	11,840	12,017	12,398	12 680
Cropped land	8 813	14,509	13,849	13 311	13,180	12,639
Mixed corn	85	501	443	460	612	694
Fodder crops	1 385	1,935	1,884	1,752	1,500 *	1,500 *

* approximate

TABLE Ag XIV

(*a*) PER 100 ACRES CROPS AND GRASS

	Workers	*No of cattle*		*Sheep*	*Horses*	*% Arable*	*Wheat*
		Total	*In milk*				
1939	2 2	28 0	9 0	85	2 6	40	5 6
1945	2 9	31 0	9 4	65	—	61	11 2

(*b*) PER WORKER—GREAT BRITAIN

	Crops and Grass	*No of cattle*		*Sheep*	*Horses*	*% Arable*	*Wheat*
		Total	*In milk*				
1939	44 5	12 5	4 0	37 8	1 2	18 1	2 4
1945	35 0	10 9	3 3	22 7		21 6	4 1

We are now 70 per cent self-sufficient, though the diet lacks the variety of that pre-war This feat has been achieved through the growing of more cereals, both for human consumption and for stock feeding Arable land now forms some 60 per cent of our cultivated land as opposed to 40 per cent pre-war (Table Ag XIII) The total area of crops grown for stock feeding has increased by over 40 per cent Big decreases in the areas under permanent grass (37 per cent decline) and bare fallow (72 2 per cent decline) are the main sources of

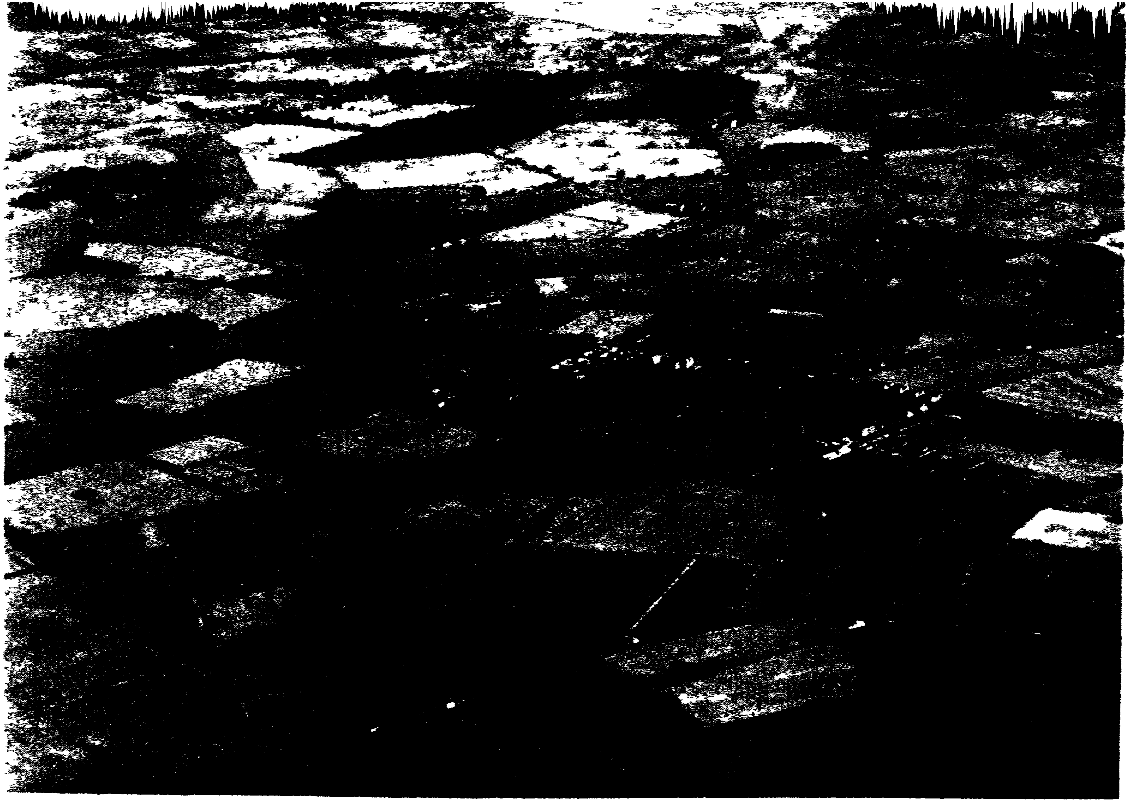
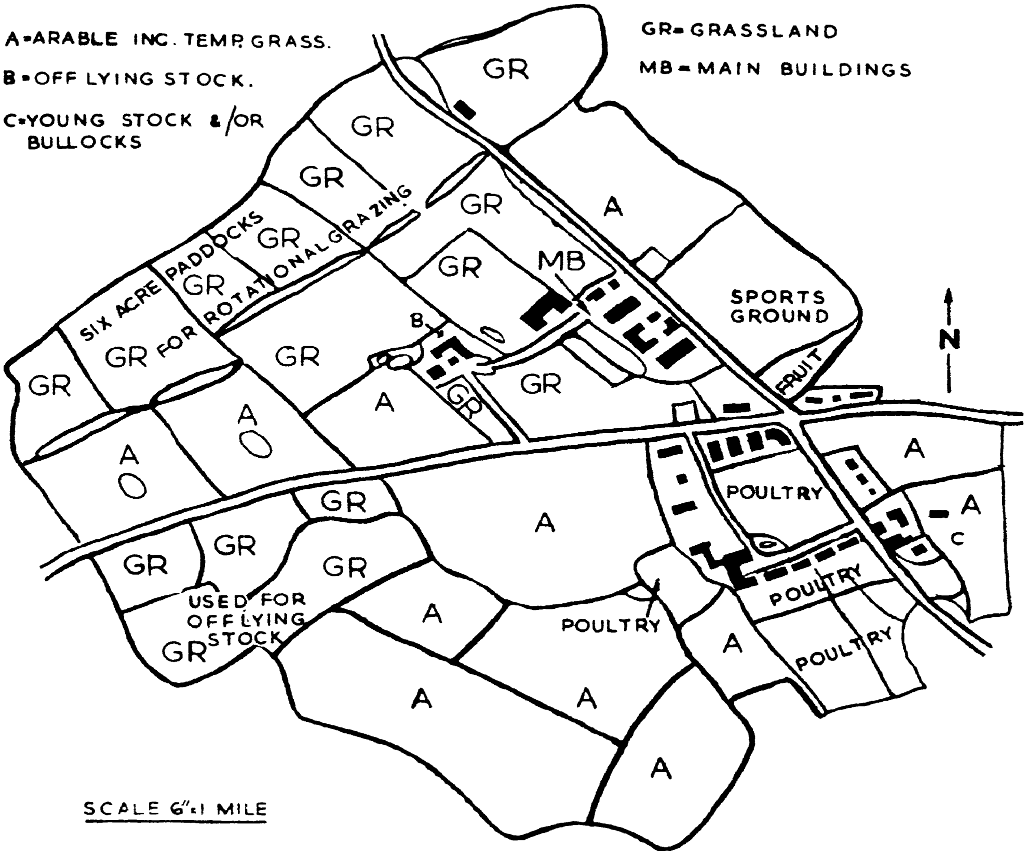


FIG. Ag 2.—*Aerial Photograph of Fig. Ag 3.*


A-ARABLE INC. TEMP. GRASS.
B-OFF LYING STOCK.
C-YOUNG STOCK &/OR BULLOCKS
GR-GRASSLAND
MB-MAIN BUILDINGS
N
SPORTS GROUND
FRUIT
MB
B
C
SIX ACRE PADDOCKS GR FOR ROTATIONAL GRAZING
GR
A
POULTRY
USED FOR OFF LYING STOCK
SCALE 6"=1 MILE

the increased acreage for cropping. High-protein crops have been introduced and the use of ensiling and drying as means of preservation for grasses and legumes for winter feeding has spread rapidly. The techniques of feeding these more bulky foods to cattle took some time to master and there was a decline in production of stock products in the early war years. Striking increases in the acreages of mixed corn, rye and rape all show the gearing of our farms to war-time needs.

Some indication of the increase in farm efficiency is shown in Table Ag XIV.

Mechanisation. The mechanisation of British farming, although it started in the nineteen-twenties and even earlier, did not progress very rapidly until after 1930. By the outbreak of war there were 55,000 tractors in use. The war imparted a substantial impetus to the mechanisation of the land and by 1942 the number of tractors had reached 120,000. The immense ploughing campaign,

TABLE Ag XV

AGRICULTURAL MACHINERY CENSUS DATA, 1944–50

(England and Wales)

Machine or implement	1944	1946	1948	1950
Power and haulage	*Number*	*Number*	*Number*	*Number*
Tractors				
Tracklayers	8,360	11,310	13,890	16,540
3 and 4 wheel	134,170	153,650	193,530	245,400
1 and 2 wheel	10,330	14,890	23,860	33,310
Total tractors	152,860	179,850	231,280	295,250
Petrol and oil engines	135,660	154,640	173,620	199,170
Electric motors	–	47,920	60,990	82,920
Waggons and carts	—	596,360	463,370	403,930
Lorries and vans	--	57,850	85,860	90,390
Liquid manure carts		10,170	12,170	12,180
Tractor trailers	—	78,940	146,680	221,070
Spraying machinery				
Power fruit sprayers	3,070	5,670	6,610	8,030
Ground crop sprayers	2,580	3,440	3,280	4,190
Tillage and cultivation				
Mouldboard ploughs				
Horse	254,980	247,170	171,180	137,880
Tractor	134,820	155,580	214,510	263,670
Ridging ploughs				
Horse	--	124,290	122,690	115,170
Tractor	-	23,150	35,560	63,100
Cultivators, grubbers, scufflers				
Horse	83,090	117,730	108,580	95,950
Tractor	67,120	83,220	100,710	139,830
Hoes—				
Horse	-	166,440	164,430	153,190
Tractor	-	11,250	18,780	40,290
Harrows—				
Disc	49,650	55,820	65,410	70,180
Spring-tooth		88,130	90,530	84,520
Others		341,040	331,650	386,560
Rollers	—	205,320	193,500	212,980

TABLE Ag XV – (*Continued*)

Machine or implement	1944	1946	1948	1950
Power and haulage	*Number*	*Number*	*Number*	*Number*
Barn and farmyard—				
Portable threshing machines	11,920	12,840	13,600	13,940
Hay and straw balers –				
Stationary	3,290	4,240	5,800	7,280
Pick-up		1,720	1,820	5,020
Loaders—other than hay –				
Tractors—fork type, jib		—	—	1,400
G.P. elevator type		—	—	2,240
Root cutters and pulpers	—	177,860	164,120	130,250
Potato sorters—				
Hand, not riddles	—	—	25,840	23,580
Power	—	—	8,260	12,320
Grinding mills, power operated	—	79,680	80,960	81,850
Hammer mills	—	8,460	12,820	18,470
Meal mixers	—	1,070	1,230	1,730
Grass driers		230	320	660
Grain driers	—	1,000	1,130	1,310
Winnowers and cleaners, power		1,730	8,250	7,900
Shearing and clipping		53,410	50,560	48,700
Mixed section—Harvesting				
Mowers over 3 ft. wide –				
Horse	145,290	150,980	135,190	107,620
Tractor	36,890	48,200	66,710	107,490
Side rakes and swathe turners	273,520	116,690	120,280	130,240
Hay rakes		178,790	180,050	179,470
Hay tedders	40,390	47,310	46,260	46,240
Hay sweeps	73,590	80,010	87,150	96,740
Hay loaders	23,270	24,180	25,770	28,960
Hay, corn and straw elevators	31,690	38,080	45,620	55,290
Binders	114,670	119,390	119,080	120,220
Combine harvesters	2,400	3,570	4,970	10,120
Green crop cutter-collectors		590	800	1,140
Green crop loaders	—	730	1,000	4,100
Silage cutters and blowers	—	—	1,050	1,220
Potato spinners	41,630	46,980	52,340	59,610
Potato elevator diggers	2,310	3,770	4,600	9,640
Complete potato harvesters	—	—	—	480
Sugar beet ploughs, lifters, harvesters, etc.	—	28,970	—	34,650
Dairying—				
Milking machines	30,560	40,360	48,130	69,170
Sterilising installations	28,740	35,170	39,960	47,140
Milk coolers	—	103,560	107,300	109,400
Sowing and fertilisers—				
Corn drills	87,090	89,630	89,810	91,340
Combined drills	11,910	16,110	19,680	23,880
Root drills	—	82,320	84,640	87,170
Broadcasters	—	9,620	11,340	13,790
Fertiliser distributors, 5 ft.	54,020	65,600	74,830	88,450
Potato planters	—	5,710	7,120	10,970
Seedling transplanters	—	3,040	4,060	5,260

shortage of skilled hand labour, and the relative prosperity of the industry, all combined to supply the impetus. The speed of the re-equipment of our farms has now slackened, but with labour likely to remain scarce and expensive it will be necessary for the farms to continue to keep their machinery up-to-date. Nearly all classes of implements, with the exception of horse machines, have shared in the rise (Table Ag XV). Most of this extra equipment was produced at home, though some of the newer designs and specialist machines came from the U.S.A. and Canada.

Housing and Management of Dairy Cattle. ***Housing systems*** (*see also Dairy farm buildings*, p. 349). Cattle—especially dairy cattle—require some form of housing, if only for milking purposes.

(*a*) *Cowshed.* The cowshed, shippon or byre, is by far the commonest system of housing used in this country, and though newer ideas are gaining ground it is likely to remain so, especially in the wetter districts where the lack of straw and inclement weather both favour the indoor system. The oldest types of shed (and one still common in many of the more isolated districts of the country) are those with either a loft or second storey over the cows, usually forming a granary or hay store. In districts where the winter is liable to be very wet or cold, this maintenance of both animals and their food under the same roof is an attractive idea. Many of these sheds fail to come up to modern hygienic standards, however, because of low roofs, bad floors, etc., and they are being replaced by modern type sheds or other housing systems. The modern shed consists of either a single or double line of cows standing either tail to tail or head to head. Normally floors are of concrete and there is no loft; lighting may be either by windows or roof-lights or both, and the stall divisions between each pair of cows are of tubular steel or concrete. Where the cows stand tail to tail there will often be feeding passage in front of the animals.

There are infinite variations in interior design of fittings, floors, mangers, etc., although usually certain minimum standards are adhered to as regards dimensions. Some of the more recent sheds have adopted yoke-tying though this is not popular with everyone. The sheds are normally equipped so that the cows may be milked where they stand, usually by machine.

(*b*) *Yards.* Yarding of dairy cattle has increased steadily in popularity over the past few years and in some cases has superseded the still existing cowshed on the farm. The main reasons for the adoption of yards are:

(i) Better stock health.
(ii) Better manure saving.
(iii) Economic use of surplus straw.
(iv) Less costly to erect and run.
(v) Adaptability to other systems if necessary.

Yards are normally of three types, either covered, semi-covered or open. It is generally agreed that covered yards aid in the conservation of the manure, but the semi-covered and open yards are cheaper to erect. Yards for dairy cattle are equipped with racks for the feeding of roughages, though as a rule the concentrates ration is fed to the animals where they are milked. Dairy stock are milked either in a normal type shed or in a milking parlour. The cowshed is used in connection with the yards as a rule where the yarding system has been adopted as an improvement for the health and cleanliness of the stock.

Milking parlours may be of several types and designs. The standard modern design is the auto-recorder where the milk is drawn by machine, weighed automatically and passed to the cooler in the dairy without exposure to the air. Alternatively, the parlour may be used in conjunction either with hand or normal bucket milking. The other unit occasionally used is a movable bail which is given a semi-permanent base for the winter period whilst the cows are yarded. (*See* Bail, Milking machines.)

(*c*) *Bail dairying.* This system calls for no permanent housing for the stock, except as already indicated, where the land is too wet or heavy to carry the stock for the whole of the winter period. In the original system the stock are allowed to lie out for the whole of the year. The essence of the method is that a movable milking parlour follows the stock to the fields. A temporary paddock is erected to gather the cows at milking time. The unit is self-contained, consisting of the " bail " and a movable dairy section. Stocks of food and water are brought out to the unit as necessary, and the whole unit moved as required by the moving of the stock or the condition of the ground. Under this system yields are less than they would be under more normal methods, but cost of production is also less and there is no capital expended on buildings.

Where buildings are poor or inadequate for the production of quality milk it has often proved cheapest to install a separate milking unit or parlour, continuing to use the sheds or stalls merely as housing for the stock. Many of our smaller herds have overcome the handicaps of scattered buildings by the use of mobile milking machines with one or more bucket units.

(*d*) *The housing of bulls.* This is a matter which has received more attention in the last few years than was previously thought necessary: it is now recognised that the temper and condition of the bull may be radically altered by a change in housing. It is desirable that a bull should live in good condition until he is proven, and adequate room for exercise is vital to this aim. A bull should have light, air, exercise room, and be able to see something of the activities around the place. The best form of housing is one which provides him with some form of sleeping place—such as a loose box—which allows a free run out into an exercise yard. Provision for catching him in a yoke from the outside of the pen should be fitted to minimise handling risks. There are numerous alternatives, such as tethering out on grass either wholly or for part of the day.

(*e*) *Housing of young stock.* Calves are generally kept in pens, either individually or in groups of up to about half a dozen. When fed by the bucket, they are normally in small groups for the convenience of feeding. Occasionally the pens are fitted with yoke fastenings so that individual feeding is simplified. Where the calves are suckled they are run either unconfined with their dams, or in pens and allowed access to their dams for limited periods only. The main essentials of housing the young calves are air, light, and freedom from draughts and damp. As they increase in age they may be run in yards, covered or semi-covered, or out on pasture, according to the time of year. Normally, the more mature heifers are allowed to lie out even through the winter period, except in the north and west country. In some parts young cattle are kept in stalls after the fashion of the more normal cowshed.

The Management of Dairy Stock. (*See* also p. 637.) The routine of managing dairy stock revolves around their feeding and milking. The normal summer management is based largely on the grazing of the stock on pasture, or occasionally their feeding with other fodder crops, either *in situ* or as soilage. With all the milking stock this has to be integrated with the twice or thrice daily collection of the animals for milking. The normal routine grazing method simply consists of allowing the stock free access to the pasture land. Amongst the things considered desirable for maximum production of good quality milk is an adequate supply of clean water within easy reach. Because of the milking collection the stock pastures for the dairy herd are normally situated close, or reasonably close to the buildings, except in the case of bail dairying (*see* Housing, p. 349).

The grassland may consist of either temporary or permanent grasses, the proportion of the former having increased in recent years (*see* Grass, p. 493). Recent developments on the management of the pastures have been devoted to increasing their production directly, and to extending their growing season. This improvement has largely been brought about by the use of better strains of grasses and clovers, which are better able to recover from cutting and grazing, and grow both earlier and later in the season. Special purpose leys to provide grazing in what are normally out of season periods are increasingly popular. This trend has virtually extended the period of summer management and shortened that of the winter correspondingly. In order to get the maximum value from this development, the system of rotational grazing has developed, and this demands a much higher standard of management. Either the stock are allowed to graze the ley for a limited period and then allowed to run back on to bare pasture in order to ruminate without destroying quantities of the ley grass by lying on it, or they are grazed only on very small sections at a time, so that every three days or so they move on to fresh ground and leave the grazed patch to rest and recover. This quick grazing down of the grass and then allowing a longish period of rest is found to increase the output of the grass and, at the same time, keeps the pasture in better condition. With the increase in the intensity of the pasture management, so the stock require closer attention. Occasionally, cows are fed during the summer period on fodder crops, such as maize, which is fed to the cows either by folding them on to the crop or by cutting and carting to the stock on pasture. The latter method is much more costly in labour so that it is not common. A new technique is to cut the grass on a pasture ahead of the cows, allow it to wilt, and then to fold them on the wilted material with an electric fence. The stock appear to prefer this wilted feed to the fresh grass (*see* Feeding, p. 465). The general routine of stock management consists of milking at about 5.30 a.m., and then turning out the stock on to a pasture whilst the shed or parlour is washed down and the milking equipment washed and sterilised. If control of grazing is practised the stock will then have to be taken off the pasture during the morning. Dry stock and heifers must be visited in their outlying fields to see that they are all fit and well; particular attention being paid in summer to the dry and in-calf stock because of the danger of summer mastitis (p. 660). The stock must also be treated in early summer with derris if they are infected with warble fly (*see* Diseases, animal). Apart from these routine visits to the stock they should need little attention save to see that they have water available and when they have to be moved from pasture to pasture. Normally there are some stock in the buildings, particularly young calves which require fresh bedding and regular feeding. Bulls may be exercised if they are not tethered out in the fields or running with stock. Apart from this, summer is a light period for the stockmen and on many farms they also work in the fields. With leys, watch must be kept on the stock for " blowing ", but care in not turning them on to wet succulent growth helps this as well as allowing them access to a little straw or hay; certain areas appear particularly prone to this ailment and greater care must be taken in those districts. The routine use of strip-cups in the cowsheds will assist in the prevention of mastitis spreading, and careful note of the condition of the stock will prevent sudden crises.

The cattle are collected for evening milking, turned out on to a fresh pasture or back to the same one, and the equipment and sheds dealt with as before. Any concentrate feeds necessary are normally given at milking times.

Winter routine is a little more intensive; the stock will have less food available on the pastures and more hand feeding will be necessary; they may have grazing outside until the end of January if the practice of folding on rape or kale is adopted; they will be lying-in for some part of the period, though some farms have started keeping the stock out day and night all through the year. Given adequate shelter and land that is dry enough this system seems to work well and does naturally lighten the work in the sheds very considerably. However, most farms keep their stock in at nights, and in many cases during the day as well, which means that in addition to the normal winter routine of milking and feeding with both hay and concentrates, they have to remove considerable amounts of soiled litter from the shed each day. The winter routine is similar to that in summer, except that in addition after each milking there are roughages to be fed, the shed to clean down and fresh litter to distribute. Foods have to be mixed and those young stock lying-in have also to be fed and littered. As the winter period is normally the dairy farmers' main calving period, special attention has to be paid to the care of the in-calf stock; they will need antenatal feeding to provide for the coming lactation and care at parturition. In addition the stockman has to watch for heat periods, particularly with the heifer stock where oestrus is brief.

The litter used is straw or peat moss, the latter being in favour where bulk control is practised in feeding, since the stock are less inclined to eat their litter. Sawdust may be used but is not popular. A system developed in the United States and tried very successfully over here, is to spread ground limestone on the floors after cleaning, instead of washing down. The sheds remain drier, there is no smell, and the cattle seem to appreciate the pleasanter atmosphere.

Attention during the winter is necessary to the health of the animals. Careful observation will usually enable any cases of general unthriftiness to be detected early. Care in the feeding and cleaning of the animals with attention in particular to their feed and udders, is essential. When cows are being kept under fairly intensive and artificial conditions, they are easily put off their feed by dirty mangers and become more susceptible to illness if they are not provided with a well-ventilated house.

Records are an important aspect of the management of dairy cows. The weighing of milk will not only help in culling the passengers in a herd, but it can be a very useful guide to the health of the animals. Milk records, together with food consumption records, will be a great help in planning the farm cropping and in checking any wastage of feed in the shed.

The golden rule in really efficient management of dairy cows is to give the individual animal individual attention. Feed her correctly, milk her efficiently, watch her carefully, and weigh her milk. The farmer should know how much she is capable of and see that she gives that amount. At the same time the young stock must also receive attention for they are the future dairy cows. Carefully bred stock should be equally carefully fed if they are to show their full potentialities. The bull, too, needs to be fed correctly if he is to remain a useful sire for the maximum length of time.

Services to Dairy Farming. ***Milk Marketing Board.*** Apart from the actual handling of milk sales and distribution throughout the country, the Board provides several other services to the dairy farmer.

National Milk Records (first taken over by the Board in 1943). The practice of *milk recording*—that is, weighing of the yields of the individual cows—had long been in use by that date, but it was mainly carried out by the important pedigree breeders to assist their sales of stock. It was done officially by local societies sponsored by the Ministry of Agriculture. The work was only done on a limited scale and the number of farmers recording was very small (Table Ag XVI).

The Board took over the milk recording societies with the idea of extending the service to as many members as possible, realising the value of records for purposes of assessing both the female and male stock in the herd. It can be seen from the above that they have achieved a good deal, although there are still nearly four-fifths of our cows unrecorded. Until September 1948 the scheme was in two divisions, Senior and Junior. By 1947 the numbers of members in the Junior scheme (which was really a training ground for the Senior scheme) were falling. In 1948, therefore, two new divisions, A and B, were started. " A " members record milk and have butterfat tests; " B " members are milk weighers only, with weekly not daily weighings. The butterfat testing service has increased rapidly over the last few years and in order to relieve the pressure on the milk-testing laboratories, " composite milk samples " are now taken; this method was introduced in 1949 (Table Ag XVII).

TABLE Ag XVI

PROGRESS OF MILK RECORDING

Year	*Herds recording*	*Members*	*% of all cows*
1914-15	306	264	—
1922-23	4,767	4,365	—
1937-38	4,767	4,302	—
1943	4,120	—	5.3
1944	8,872	—	9.9
1945	13,320	—	13.9
1946	16,820	—	16.7
1947	18,200	—	17.5
1948	20,850	—	—
1949	21,816	—	—
1950	23,817	—	—

TABLE Ag XVII

PROGRESS OF BUTTERFAT TESTING

Year to 1 Oct	*Number of tested samples*
1937 (refers to cows)	13,174 (*Min of Agric Jour*, xlv)
1943 (9 months)	297,000
1944	853,000
1945	1,242,000
1946	1,677,000
1947	1,994,000
1948	2,514,000
1949	2,195,000 Normal 420,000 Composite

TABLE Ag XVIII

AVERAGE YIELD FOR EACH BREED OR BREED TYPE

(Three years Based on lactation yields 305 days)

Breed or breed type	*Average lactation yield (lb)* *Cows*			*1st calf heifers*		
	1946-7	1947-8	1948-9	1946-7	1947-8	1948-9
Ayrshire	7552	7530	8088	6551	6557	—
Friesian	8555	8477	9141	7259	7245	—
Shorthorn	6929	6819	7365	5558	5567	—
Red poll	7234	6879	7476	5791	5750	
Jersey	6715	6652	7051	5562	5494	—
Guernsey	7065	6907	7473	6140	6057	—
South Devon	6215	6431	6738	4916	5153	—
Mixed and others	7050	7012	7602	5983	6063	—
Total all	7390	7340	7986	6226	6278	—

Average butterfat (cows) 1947-8 3.75 %, and 1948-9 —3.79 %

The composite method of sampling took place voluntarily during 1949, becoming compulsory after 1 October. By September 1949, 90 per cent. of the tests were of this type. In Table Ag XVII the figure for 1949 comparable with 1948 is 3,035,000 tests.

The N.M.R. service supplies a good deal of valuable information both to the breeders and to the Bureau of Records (*q.v.*). Yield figures are given in Table Ag XVIII.

Bureau of records. This section of the Board's services began work in October 1946. The bureau is divided into three parts: *Lactation, Progeny Testing*, and *Investigation.*

The *Lactation* section deals with all the basic data which comes in from the Recorders of the Milk Records scheme in the form of lactation record cards. These data are filed and indexed to provide easily accessible information for Breed societies, A.I. centres and private breeders. The *Progeny testing* section also uses these cards to amass daughter records, and where possible daughter-dam comparisons for the bulls of the breeders. In order to make this section more useful they are trying to extend the practice of earmarking all calves at birth so that the whole of a bull's progeny may be traced. The progeny group is particularly concerned with an extension of its work in connection with the new scheme for testing A.I. bulls (see below). The *Investigation* section supplies data on all aspects of herd management, statistical information for reports and breed societies, and also makes analyses of all the lactation record material supplied by N.M.R. It will be some years before the full value of this section can be realised as the amount of basic data available is small as yet.

TABLE Ag XIX

PROGRESS OF ARTIFICIAL INSEMINATION

Year	*Members*	*Inseminations*	*Conception %*
1946	922	6,401	
1947	4,420	25,535	
1948	12,766	90,173	
1949	33,249	255,567	63·7
1950	53,908	431,370	64·0

TABLE Ag XX

INSEMINATIONS BY BREED 1949

Breed	*Inseminations*	*% of total*
Friesian	169,533	39·3
Shorthorn	89,671	20·8
Ayrshire.	55,068	12·8
Colour marking beef bulls .	52,459	12·1
Guernsey	33,398	7·7
Jersey	12,559	2·9
North Devon . . .	8,879	2·0
Other breeds	9,803	2·4

Artificial insemination. In 1945 the Board took over two centres for the development of artificial insemination on a communal basis as had been done for some years in U.S.S.R., U.S.A., and Denmark. In this field of work they have not a complete monopoly, but they now control the majority of the work apart from one or two private and research centres. The rise in popularity has been meteoric and shows the vast need for such a service which helps a small farmer with a few cows to grade-up by using bulls that he would be unable to afford otherwise. Membership in four years has increased itself nearly sixty times, and nearly half a million cows were inseminated last year. It is expected that the service will eventually cater for some 1,000,000 inseminations each year, requiring a stud of over 1,000 bulls, including those on test (Tables Ag XIX and XX). Bulls at the centres at 31 March 1950 numbered 505 (Fig. Ag 4).

The A.I. service run by the M.M.B., forming as it does the largest cattle breeding organisation in the world, has initiated a progeny-testing scheme to select proven bulls free from undesirable factors for use in the centres. This is essential since a bull potential for good or evil as far as breeding goes is multiplied twenty times or more at an A.I. centre. The essence of the scheme is to test mate groups of young bulls with cows selected from the better herds of the district; then to hold them in reserve until at least twenty first lactation daughter records are available. By random mating environmental effects are cancelled out and the bulls may be compared with others in the group to select the best.

Other services. There are twelve M.M.B. communal grass-drying plants in operation and more may be added. They are useful in areas where small farms are numerous and the farmers cannot afford individual machines. Output in 1949 was 8470 tons at 13 per cent. protein; this figure was disappointingly low.

Water and electricity services. An adequate supply of both is desirable and almost essential if milk is to be produced up to modern standards as regards hygiene and quality. Investigation into the state of our farms in 1941 included these services, and brought out the following points:

Water

(*a*) 47 per cent. farmhouses and 37 per cent. farm buildings have a piped supply generally from a public mains.

(*b*) 45 per cent. farmhouses and 27 per cent. buildings rely on wells.

(*c*) 8 per cent. farm houses and 36 per cent. buildings rely on other sources, such as roof collection, streams, or have no supply at all. There are just over 1 per cent. houses and 15½ per cent. buildings which fall into the latter category.

(*d*) Field supplies are commonly streams and rivers. Over 10 per cent. have no supply to any field and under 16 per cent. a piped supply to one or more fields.

(*e*) Larger holdings are more likely to have piped supplies. Smaller holdings have more undesirable sources and a much higher percentage of waterless farms.

(*f*) 20 per cent. farms suffer seasonal shortages.

Electricity

(*a*) 27 per cent. of all holdings over 5 acres in England and Wales have electricity, 90 per cent. being from public supplies.

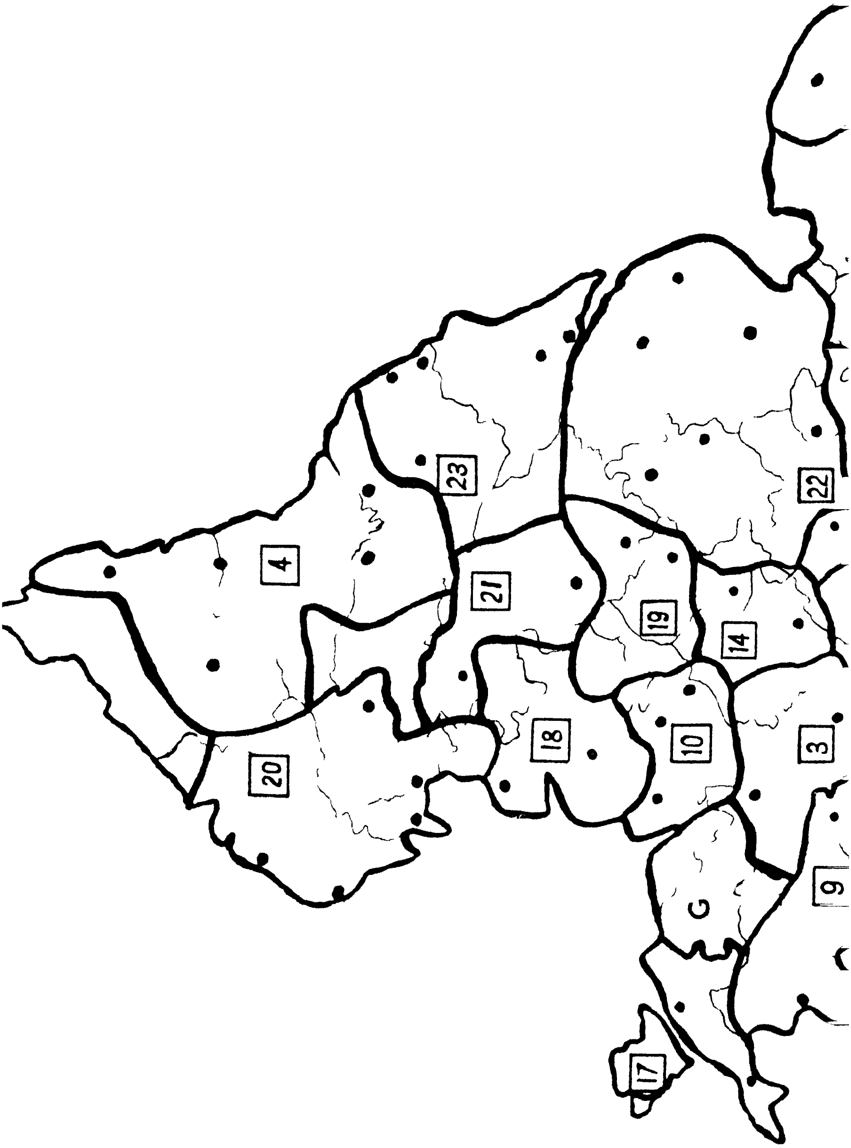
(*b*) The farms nearer urban centres have most chance of a supply; the figure is over 50 per cent. in some Home Counties.

(*c*) Larger holdings have a greater proportion equipped except for small-holdings near urban centres.

(*d*) 52·9 per cent. farms with current are supplied for farmhouse alone and 2·8 per cent. for buildings alone.

(*e*) Only one quarter of farmhouses are supplied with power, and three quarters where both farmhouse and buildings are wired for current.

(*f*) Larger dairy herds are generally associated with a supply of power and light.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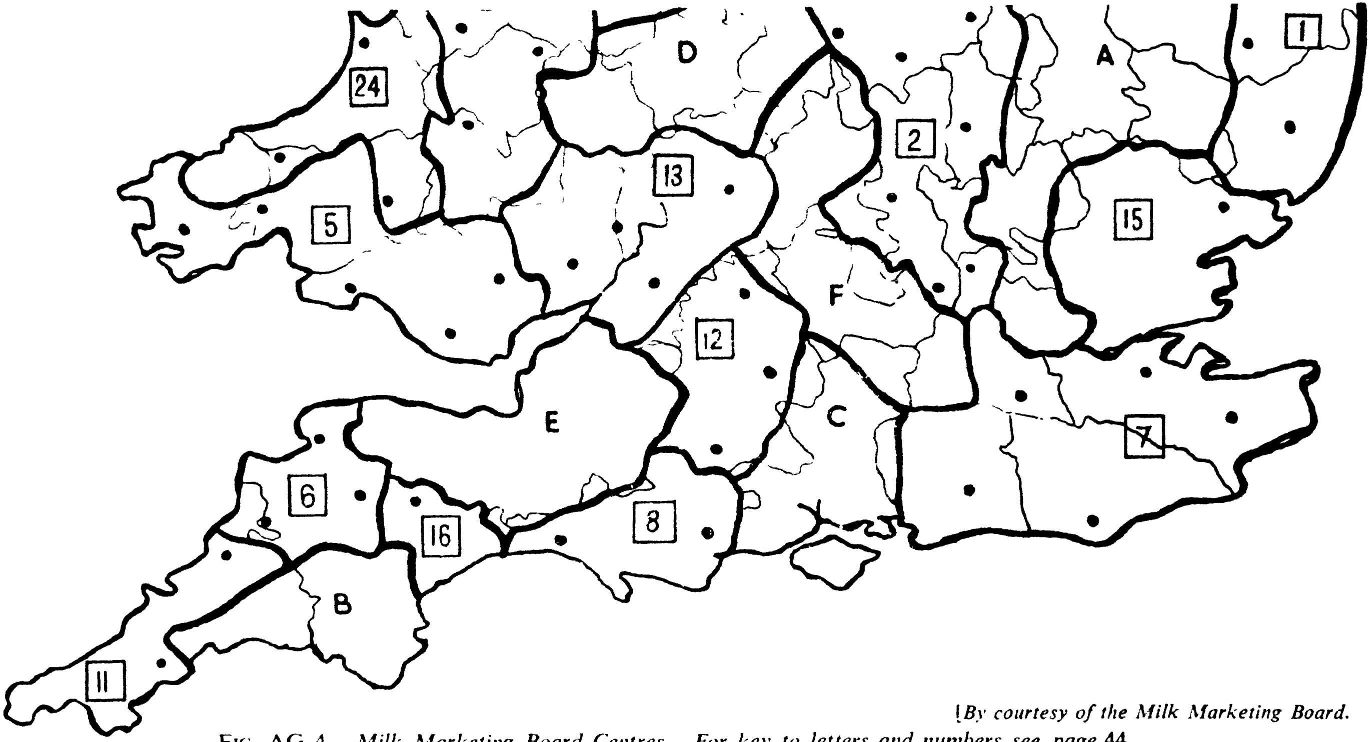


[By courtesy of the Milk Marketing Board.

FIG. AG 4.—*Milk Marketing Board Centres. For key to letters and numbers see page 44.*

ARTIFICIAL INSEMINATION COVERAGE IN ENGLAND AND WALES

Key ☐ Main Centre
● Sub-Centre or Telephone point
Thick black lines indicate Centre Boundaries.

MILK MARKETING BOARD CENTRES

Map no.	*Main centre*	*Sub-centres and/or telephone points attached*
1	Beccles, Suffolk	Aylsham; Otley; Wymondham
2	Little Horwood, Bucks	Aylesbury; Bedford; Dunchurch; Lutterworth; Northampton; Oundle; Pinner; Slough
3	Cheswardine, Salop	Bridgnorth; Ellesmere
4	Shincliffe, Durham	Alnwick; Hexham; Newcastle; Richmond; Stokesley
5	Carmarthen, Carms	Bridgend; Haverfordwest; Porth; Swansea; Whitland
6	Torrington, Devon	Barnstaple; Holsworthy; Lapford
7	Whiligh, Sussex	Lewes; Maidstone; Redhill; Storrington; Wye
8	Sturminster Newton, Dorset	Bridport; Sturminster Marshal
9	Welshpool, Mont.	Builth Wells; Caersws; Dolgelly; Dorrington; Knighton
10	Tarporley, Cheshire	Congleton; Little Stanney; Over Peover
11	Praze, Cornwall	Camelford; Grampound
12	Chippenham, Wilts	Swindon; Tisbury; Upavon
13	Gloucester, Glos	Coleford; Northleach; Thornbury; Usk
14	Tean, Staffs	Belper; Lichfield
15	Writtle, Essex	Colchester
16	Honiton Clyst, Devon	Tiverton Junction
17	Llangefni, Anglesey	Bangor; Pwllheli
18	Whalley, Lancs	Garstang; Wigan
19	Buxton, Derbys	Chesterfield; Norden, Wentworth
20	Penrith, Cumberland	Aspatria; Egremont; Kirkby Stephen; Milnthorpe; Ulverston
21	Burley, Yorks	Kirkburton; Settle
22	Sutton Bonington, Leicester	Donington; Market Rasen; Newark; Oakham; Retford; Willoughby
23	Yorks, Yorks	Beverley; Hedon; Kirkby Moorside; Seamer; Whitby
24	Felin Fach, Cards	Aberystwyth; Llandilo; Newcastle Emlyn
		NON-BOARD CENTRES
A	Cambridge	Cambridge and District Cattle Breeders Ltd.
B	Darlington Hall	Darlington Hall Cattle Breeding Centre
C	Lyndhurst	Hampshire Cattle Breeding Soc. Ltd.
D	Bromsgrove	Avoncroft Cattle Breeders Ltd.
E	Ilminster	Messrs. Horlicks Farms and Dairies Ltd.
F	Reading	Ministry of Agriculture and Fisheries
G	Ruthin	

STATISTICS

AGRICULTURAL RETURNS

June returns, 1948–49 (England and Wales)
Livestock (000)

Description	4 *June* 1948	4 *June* 1949
Cows and heifers in-milk and cows in-calf	2,794	2,880
Heifers in-calf	709	718
Bulls in use or being reared	149	140
Other cattle	3,689	3,942
Total cattle	7,341	7,680
Sheep over one year old	6,143	6,564
Sheep under one year old	4,716	5,160
Total sheep	10,859	11,724
Sows and gilts in-pig or for breeding	249	262
Boars	28	33
All other pigs	1,346	1,858
Total pigs	1,623	2,153
Fowls	47,863	56,746
Ducks, geese and turkeys	3,990	4,229
Total poultry	51,853	60,975
Total horses	538	469

Crops and Grass (000 acres)

Description	4 *June* 1948	4 *June* 1949
Wheat	2,188	1,900
Barley	1,897	1,883
Oats	1,992	1,945
Mixed corn	588	669
Rye for threshing	57	60
Rye for green fodder	5	5
Beans for stock feeding	80	102
Peas ,, ,,	45	39
Potatoes	1,117	929
Turnips and swedes	355	339
Mangolds	272	267
Sugar beet	405	412
Rape	104	116
Cabbages, kale, etc., for stockfeed	189	205
Vetches	38	28
Mustard	38	37
Flax for fibre	14	17
Flax for linseed	86	58
Hops	23	22
Orchards and soft fruits	295	303
Vegetables, flowers and glass crops	583	530
Other crops and barefallow	283	298
Total tillage	10,654	10,164

STATISTICS—(*contd.*)

Crops and Grass (000 acres)—*contd.*

Description	4 *June* 1948	4 *June* 1949
Clover, sainfoin and temporary grasses:		
(i) For mowing	2,079	2,315
(ii) For grazing	1,378	1,376
Total temporary grass	3,457	3,691
Total arable	14,111	13,855
Permanent grass:		
(i) For mowing	2,655	2,629
(ii) For grazing	7,608	7,821
Total permanent grass	10,263	10,450
Total acreage crops and grass	24,374	24,305
Rough grazings	5,559	5,533

LABOUR (000)

(All holdings over 1 acre)

Description	4 *June* 1948	4 *June* 1949
Regular male workers	506·5	526·1
Regular female workers (not W.L.A.)	57·3	55·8
Women's Land Army	16·5	11·2
Prisoners of war	11·4	—
Casual workers	149·1	152·3
Total male workers	616·7	631·1
Total female workers	124·1	114·3
Total workers	740·8	745·4

VALUE OF AGRICULTURAL OUTPUT

(United Kingdom) £ 000

	1936–37 *to* 1938–39 *average*	1943–44 *at pre-war prices*
Farm crops	60,972	108,396
Livestock products	198,453	155,478
Meat	97,622	62,965
Eggs	22,422	12,582
Milk	71,029	73,728
Wool	3,267	2,707
Hides and skins	4,113	3,496

STATISTICS—(*contd.*)

VALUE OF AGRICULTURAL OUTPUT—*contd.*

(United Kingdom) £ 000

	1936-37 *to* 1938-39 *average*	1943-44 *at pre-war prices*
Production from gardens, allotments, etc.	22,179	24,540
Sundries including flax and flowers	5,924	4,459
Total gross output	287,528	292,873
Deduct—feedingstuffs, etc., imported	64,611	17,320
Total net output	222,917	275,553

LAND UTILISATION SURVEY 1930-38

Acres

Land usage	*Scotland*	*Wales*	*Isle of Man*	*England*
Arable	3,128,649 (3,251,000)	535,890	65,503 (13,914,000)	8,339,379
Permanent grass	1,471,455 (1,188,232)	2,167,830	19,910 (10,450,000)	15,307,984
Orchards	835	3,400	—	257,122
Forest and woodland	1,094,294	294,228	2,780	1,827,899
Rough grazings	13,011,323	1,906,460	44,750	3,812,644
Houses with gardens	155,273	73,270	3,840	1,487,503
Land agriculturally unproductive	207,726	117,670	4,203	1,609,635
Total area	19,069,555	5,098,748	140,986	32,642,166

TOTAL AREA OF GREAT BRITAIN—56,951,455 ACRES

Average Food Consumption—Great Britain
(per head per week)

	Unit	1907	1924-28	1934-38	1944 *civilian*	1946
Wheat, cereals and flour	ounces	64·0	63·7	66·7	78·0	76·0
Meat and bacon	,,	44·6	45·3	43·5	36·6	31·0
Fish	,,	13·5	12·9	7·6	5·3	15·0
Eggs (shell equiv.)	number	2·1	2·2	3·7	3·9	?
Milk—liquid	pints	3·0	3·1	3·2	4·6	4·9
condensed, etc.	,,	—	1·2	0·6	0·5	0·4
Butter	ounces	4·9	4·7	7·6	2·4	3·5
Cheese	,,	2·7	2·9	2·7	3·1	2·9
Margarine	,,	1·5	3·8	7·8	9·9	8·1
Potatoes	,,	58·2	59·1	54·0	91·0	91·5
Fruits and nuts	,,	22·8	31·1	34·5	17·9	?
Sugar	,,	24·6	26·5	29·9	23·4	24·0

1946 estimates.

STATISTICS—(*contd.*)

PRE-WAR LAND LOSSES *
(England and Wales)

Year	*Buildings and general construction*	*Sports grounds*	*Air Ministry*	*War Office*	*Other*	*Total*
1927–28 to 1933–34 . Average:	42,000	10,000	600	200	700	53,500
1934–35 .	57,000	11,000	3,000	200	2,600	73,800
1935–36 .	55,000	13,000	10,000	1,500	—	79,500
1936–37 .	56,000	11,000	10,900	2,000	100	80,000
1937–38 .	56,000	14,000	12,200	4,700	700	87,600
1938–39 .	54,000	10,000	24,500	8,000	2,100	99,400
12 Years total.	572,000	129,000	64,800	18,600	10,400	794,800

* From the Scott Report.

Refs.: L. Dudley Stamp, *The Land of Britain, its use and misuse*; *Report of the Committee on Land Utilisation in Rural Areas* (Scott); *Monthly Digest of Statistics*, H.M. Stationery Office; *Farm Buildings*, Post-War Building Studies No. 17, H.M.S.O.; *National Farm Survey of England and Wales*: Summary Report, H.M.S.O.; *Country Planning, Agricultural Economics Research Institute*, Oxford; Farmer and Stockbreeder Year Books, various; National Milk Records Reports, various; *Milk Facts and Figures* issued by the M.M.B Publicity Department; *Farming and Mechanised Agriculture* (1948), ed. Sir R. G. Stapledon; *Artificial Insemination Service* (M.M.B.): Plan for Progeny tests of young bulls (unpublished); Martelli (1952), *The Elvedon Enterprise*; Smith (1948), *Farm Machinery and Equipment*; Culpin (1951), *Farm Mechanisation*; Fishwick (1947), *Dairy Farming: Theory and Practice*, London; Agriculture Act (1947), H.M.S.O.; Cochrane (1946), *The Milch Cow in England*, London; Holmes (1946), *Revolution in Agriculture*, London; Cookson (1945), *Dairy Cows and Their Management*, London; Field and McDowell (1946), *Dairy Enterprises*, Chicago; Robinson (1946), *Good Milk Farming*, London; Whyte (1946), *Crop Production and Environment*, London; Russell (1945), *Agriculture—To-day and To-morrow*, London; Taylor and Taylor (1943), *World Trade in Agricultural Products*, New York; Orwin (1942), *Speed the Plough*; Russell *et al.* (1942), *Farming Handbook*, Norwich; Watson and More (1949), *Agriculture*, Edinburgh; Stapledon and Davies (1941), *Ley Farming*, London; Garrett *et al.* (1943), *Farming Handbook No.* 2, Norwich; Maxton (Editor) (1936), *Regional Types of British Agriculture*, London; Hunter (Editor) (1931), *Encyclopedia of Scientific Agriculture*, London.

AIR. A mixture of gases surrounding the earth of composition by volume: nitrogen, 78·40; oxygen, 20·94; argon, 0·63; carbon dioxide, 0·03, together with water vapour and traces of the rare gases. The average pressure at sea level is 14·73 lb./sq. in.

Compressed air is often used for discharging milk from tanks. Frothing and occlusion of air in milk can lead to low specific gravity and hence low values for the solids-not-fat. This can be avoided by gentle handling of the milk and the absence of leaking glands in pumps, leaking joints, etc. *See* Aeration.

AIR-BORNE INFECTIONS. *See* Starters.

ALBUMIN. The albumin in milk is called *lactalbumin* and is not identical with serum albumin although similar in amino-acid content. It can be prepared from milk by removal of casein and globulin by saturation with magnesium sulphate and then adding 0·25 per cent. acetic acid, standing and filtering off the albumin. Albumin can be obtained in hexagonal, double-refracting crystals of limited stability. It is denatured and coagulated by heat and probably 5 to 10 per cent. is coagulated by ordinary pasteurisation (30 min. at 62·8° c.). As a protein, lactalbumin is characterised by a low nitrogen and a high sulphur content.

Refs.: Richmond; Davies; Rogers; Marsden (1953), *DSA*, **15**, 167; Rowland (1938), *JDR*, **9**, 30, 42, 47.

ALCALIGENES. A genus name given by American bacteriologists to a group of gram-negative rods producing alkali, *e.g. Alcaligenes fæcalis. See* Classification.

Ref.: Bergey.

ALCOHOL. Ordinary alcohol is ethyl alcohol C_2H_5OH. It is produced by yeasts and some bacteria as a by-product of fermentation and so is a flavour constituent in kefir (p. 566) and some cheese (p. 213).

Refs.: Prescott and Dunn; Whittier and Webb; Nicholls (1948), "The Determination of Alcohol", *Roy. Inst. Chem.*

ALCOHOLS. The ordinary aliphatic alcohols have the formula $R.CH_2OH$. In the dairy laboratory ethyl alcohol (68 per cent.) is used for the alcohol test for souring milk (p. 49). Amyl alcohol $C_5H_{11}OH$ is used in the Gerber test to assist the separation of fat. Caprylic alcohol (octyl alcohol) is useful as an inhibitor to foaming.

Ref.: Tyler.

ALCOHOL-ALIZARIN TEST. *See* Acidity of milk.

ALCOHOL-GLYCEROL RENNET. *See* Rennet.

ALCOHOL TEST FOR MILK. Although fresh milk is not precipitated by the addition of an equal volume of 68 per cent. alcohol, souring milk is coagulated, and this forms the basis of the *alcohol test* for hygienic quality or degree of souring. The test is usually combined with a *p*H indicator test, as in the *alizarin-alcohol test* of Morres. The alcohol test is particularly useful for determining the stability of milk to evaporation and sterilisation by heat. The alcohol acts by dehydrating and denaturing the protein and gives a positive test with colostrum and bad mastitis milks, and also with milks likely to give sweet curdling due to rennin production by *Bacillus mycoides* and related organisms. Milks vary in their sensitivity to alcohol especially in relation to season and region. *See* Acidity of milk; Sweet curdling.

Ref.: Eddison *et al.* (1951), *JDR*, **18**, 43.

ALCOHOLIC FERMENTATION IN MILK. Milk does not undergo alcoholic fermentation so readily as fruit juices and cereal extracts, as most yeasts cannot ferment lactose, the sugar in milk.

Some common milk bacteria, *e.g.* the coli aerogenes group, produce small amounts of alcohol, and a few *Saccharomyces* and some *Torulæ* are able to ferment lactose.

The chief interest, however, centres around the cultured milks, which often contain alcohols produced by symbiotic fermentation between yeasts, lactobacilli, and other bacteria. These cultured milks are common in the Balkan countries, Asia Minor, and South Russia. In Russia, kumys (or koumiss) is extensively drunk, and the fermentation is the result of a mixed culture of streptococci, lactobacilli, and yeasts. Kefir is a special type containing small clusters of these three organisms, which form a tangled mass resembling a tiny cauliflower head. It is necessary to inoculate a granule in order to propagate the culture, and the granules may be dried and kept for some time in a viable condition. Alcoholic milk drinks are delightfully invigorating and pleasant to drink in hot weather, and they could with advantage be popularised in this country.

Refs.: Whittier and Webb; Burke; Orla-Jensen; Prescott and Dunn.

ALDEHYDES. A class of highly reactive, odoriferous organic substances of the formula R . CHO. Formalin (p. 482) is the first member of the group.

Ref. : Tyler.

ALDEHYDE REDUCTASE (SCHARDINGER) ENZYME. Fresh milk has the property of reducing methylene blue in the presence of formaldehyde. The enzyme responsible is known as the Schardinger enzyme and may be identical with xanthine oxidase.

Ref. : Wilson *et al.*

ALDEHYDE TEST (Fat Oxidation). *See* Auto-oxidation.

ALFA PROCESS. *See* Buttermaking machines.

ALFALFA. The American name for lucerne. *See* Feeding.

ALGINATES. *See* Stabilisers.

ALIMENTARY CANAL. A general term for the whole of the food ingesting and digestive tract. It includes the mouth or buccal cavity, pharynx, oesophagus, stomach(s), duodenum, jejunum, ileum, colon, and rectum. *See* Digestion in the ruminant; Enzymes.

ALIPHATIC. Organic compounds having an open chain structure as distinct from the aromatic or ring structure.

ALIZARIN-ALCOHOL TEST. *See* Acidity of milk; Alcohol test.

ALKALIS. A term applied to caustic soda or sodium hydroxide NaOH, caustic potash KOH, and sodium carbonate Na_2CO_3. Many other salts of soda and weak acids have alkaline properties, *e.g.* sodium metasilicate Na_2SiO_3 and trisodium phosphate Na_3PO_4. All these are of great importance in the dairy industry for cleaning and degreasing purposes and are the main constituents of detergents (p. 368).

ALLANTOIS. A membranous bladder which contains the foetus in a bath of amniotic fluid.

ALLERGY. Allergy is a term that is used loosely to describe a wide variety of reactions to the entrance of foreign tissue matter or metabolites into the body, whether via the stomach or blood stream. In a broad sense it includes hypersensitiveness, anaphylaxis, and all the immunity phenomena produced as the result of the introduction of an antigen (p. 56). Of special interest is the observation that some children and adults cannot, or do not like to drink milk. Thus amongst school children it is generally recognised that about 55 per cent. like milk, 40 per cent. are indifferent and 5 per cent. do not like it. There is no cast-iron line of demarcation between inability to digest a foodstuff and allergy, but the latter term is best reserved to describe an unfavourable reaction (*e.g.* a feeling of unwellness or a rash) to the ingestion of small amounts of the foodstuff in question. The phenomenon is usually, but not necessarily, related to specific proteins in the foodstuff.

Ref. : Wilson and Miles.

ALLOLACTOSE. An analogue of lactose (p. 600) which has been isolated from human milk. *See* Gynolactose.

Refs. : Davies ; Rogers.

ALLOY. A mixture of metals. The most commonly used alloys in dairying are : (i) the bronzes ; (ii) aluminium alloys with silicon, manganese, and copper (*see* Aluminium) ; (iii) solder ; (iv) stainless steels. Copper-containing alloys should be avoided. *See* Flavours; Metals.

ALTERNATING CURRENT. Most mains supplies are now A.C. voltage 220-230 and of frequency 50 cycles. Direct current (D.C.) is still supplied in some areas, and great care should be taken to avoid connecting instruments designed for A.C. to D.C. otherwise serious damage may be done.

ALUMINIUM. This metal is characterised by its extreme lightness (sp. gr. 2·7 iron 7·86) and susceptibility to alkalis and acids. Its application in the dairy industry has been confined mainly to storage tanks and rail tankers. The pure metal is rather soft for use and usually alloys are now employed, especially those incorporating silicon. In cleaning aluminium plant and utensils care must be taken to incorporate a fair proportion of silicate, *e.g.* 25 per cent. sodium metasilicate, in the detergent. Souring milk and whey attack aluminium and cause " pitting ", and the 1 per cent. phosphoric acid used for removing milk stone on pasteurising plant will also attack aluminium. Aluminium is non-toxic and no flavour is imparted to milk until 9 p.p.m. is reached.

The alloys which appear to be most suitable for use in the dairy industry are those of aluminium with silicon, manganese, and magnesium. The copper-containing alloys should be avoided. *See* Churns ; Detergents; Metals.

Refs. : Botham and Bryson (1953), *JDR*, **20**, 154 (corrosion) ; Tutt (1953) *D*, **70**, 453 ; West (1947), *JSDT*, **1**, 31.

AMBIENT. This term is used in refrigeration to refer to the air surrounding the cooled material. Thus the ambient temperature is the prevailing atmosphere temperature round the plant, not necessarily the atmospheric shade temperature.

AMERICA, DAIRYING IN.

Refs. : White *et al.* (1953), *JSDT*, **6**, 219 ; (1953), Publ. Hlth. Serv. Bull. Wash. 229 (public health and legal); Dahlberg *et al.* (1953), Publ. Nat. Acad. Sci. Nat. Res. Counc., 250 (regulations); Agricultural statistics, 1952, U.S. Dept. Agric.; Trout (1953), *DSA*, **15**, 241, 333 ; Vanner (1953), *JSDT*, **6**, 221 ; Marsden, 227 ; Johnson and Mighell (1949), *IDC*, **4**, 696 ; Rogers (1947), *JSDT*, **1**, 61 (milk plant); Min. Agric. (1947), " Agriculture Overseas ", Report No. 5, " Technical Aspects of Milk Production in N. America ", H.M.S.O. ; Min. Agric. (1946), Report No. 1, " Milk in North America," H.M.S.O. ; *State Milk and Dairy Legislation* (1941), Washington ; Foot (1937), *Observations on American Dairy Husbandry*, London.

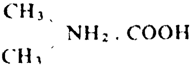
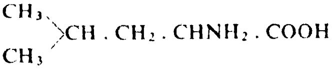
AMERICAN KNIVES. A special multiple knife with parallel cutting edges is now universally used in making factory Cheddar and similar cheese. It replaces the old English breaker, which is still used on a few farms. *See* Cheesemaking.

AMINO ACIDS. These are produced by the substitution of an *amino* group, NH_2 for a hydrogen atom in a molecule of a fatty acid.

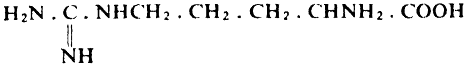
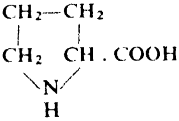
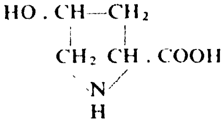
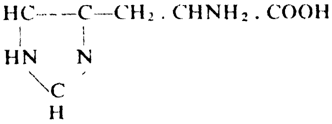
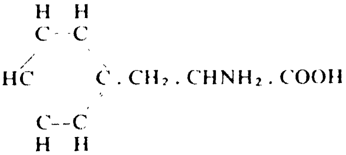
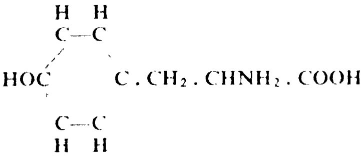
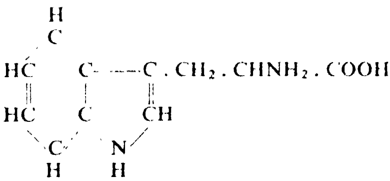
$$\underset{\text{acetic acid}}{CH_3 . COOH} \qquad \underset{\text{glycine}}{CH_2(NH_2) . COOH}$$

The formulae of the more important amino acids are as follows :

COMMON AMINO ACIDS

Glycine	$CH_2NH_2 . COOH$
Alanine	$CH_3 . CHNH_2 . COOH$
Valine	 $\begin{matrix} CH_3 & \\ & NH_2 . COOH \\ CH_3 & \end{matrix}$
Leucine	 $\begin{matrix} CH_3 & \\ & \rangle CH . CH_2 . CHNH_2 . COOH \\ CH_3 & \end{matrix}$
Isoleucine	$\begin{matrix} CH_3 . CH_2 & \\ & \rangle CH . CHNH_2 . COOH \\ CH_3 & \end{matrix}$
Serine	$CH_2OH . CHNH_2 . COOH$
Threonine	$CH_3 . CHOH . CHNH_2 . COOH$
Cysteine	$CH_2SH . CHNH_2 . COOH$
Cystine	$\begin{matrix} S—CH_2 . CHNH_2 . COOH \\ \vert \\ S—CH_2 . CHNH_2 . COOH \end{matrix}$
Methionine	$CH_3 . S . CH_2 . CH_2 . CHNH_2 . COOH$
Aspartic acid	$HOOC . CH_2 . CHNH_2 . COOH$

AMINO ACIDS

Asparagine	$H_2NOC . CH_2 , CHNH_2 . COOH$
Glutamic acid	$HOOC . CH_2 . CH_2 . CHNH_2 . COOH$
Glutamine	$H_2NOC . CH_2 . CH_2 . CHNH_2 . COOH$
Lysine	$CH_2NH_2 . CH_2 . CH_2 . CH_2 . CHNH_2 . COOH$
Hydroxylysine	$CH_2NH_2 . CHOH . CH_2 . CH_2 . CHNH_2 . COOH$
Arginine	 $H_2N . \underset{\underset{NH}{\parallel}}{C} . NHCH_2 . CH_2 . CH_2 . CHNH_2 . COOH$
Proline	
Hydroxyproline	
Histidine	
Phenylalanine	
Tyrosine	
Tryptophan	

Proteins are complexes of amino acids and break down to yield amino acids in the last stage of degradation. Amino acids are produced in the ripening of cheese especially those which attain a *p*H of near 7 or over. Very ripe Cheddar cheese may yield crystalline nodules of tyrosine, an aromatic amino acid. *See* Albumin; Casein; Cheese; Globulin; Nutritive value.

Refs.: Mitchell and Hamilton (1929), *The Biochemistry of the Amino Acids*, New York; Block and Bolling (1945), *The Amino Acid Composition of Proteins and Foods*, Illinois; Barton-Wright (1946), *Practical Methods for the Microbiological Assay of the Vitamin B Complex and Essential Amino Acids*, London; Stein *et al.* (1946), *Amino Acid Analysis of Proteins*, New York; Richmond; Davies.

AMMONIA. Ammonia NH_3 is a violently pungent gas liquefying at $-33°$ C. and very soluble in water. (i) *In dairy products:* Ammonia is liberated by moulds in certain types of cheese and contributes to the flavour of the well-ripened, blue-veined cheese when the *p*H rises above 7 (*see* Cheese). Some cheese stores will for this reason smell strongly of ammonia. (ii) *In refrigeration:* Ammonia is commonly used in refrigeration plant in dairying, whether of the brine or direct-expansion type. *See* Refrigeration.

Refs.: Davies; Richmond; Strogyli *et al.* (1951), *JDS*, **34**, 219.

AMNION. The same as Allantois.

AMORPHOUS. Without systematic shape. Non-crystalline.

AMPÈRE. The practical unit of electric current (*see* Ohm's law). One ampère-hour is 3600 coulombs.

AMPHOTERIC. This term is used loosely in more than one sense but fundamentally it indicates the power possessed by a substance to behave both as an acid and a base. In dairying the chief substances of interest are the proteins in milk and milk products especially cheese. Thus casein can combine with acids and with alkalis

$$\begin{aligned}
&\text{casein} + HCl && \rightarrow \text{casein hydrochloride (at } p\text{H} < 4{\cdot}6) \\
&R_1 . NH_2 + HCl && \rightarrow R_1 . NH_2 . HCl \\
&\text{casein} + NaOH && \rightarrow \text{sodium caseinate (at } p\text{H} > 4{\cdot}6) \\
&R_2 . COOH + NaOH && \rightarrow R_2 . COONa + H_2O
\end{aligned}$$

See Acidity of milk ; Buffers.

Ref.: Rogers.

AMYL ALCOHOL. An alcohol $C_5H_{11} . OH$ used in the Gerber test to assist in the separation of the fat. *See* Fat.

AMYLASE. An enzyme which splits starch into sugars and may be present in milk. *See* Enzymes.

ANABOLISM. That aspect of metabolism (p. 683) which is concerned with building up living tissue.

ANAEMIA. A condition characterised by a reduced number of red blood corpuscles, normally about 5,000,000,000 per ml. in human blood. The feeding of milk alone without iron and copper supplements can lead to a form of nutritional anaemia in children. The young suckling has a store of these elements in the liver sufficient for the first few months of life. *See* Nutritive value.

ANAEROBES. A general term for bacteria growing only in the absence of air or oxygen. The more oxygen-susceptible are known as "strict anaerobes". *See* Aerobic ; Classification.

Refs.: Weinberg, Nativelle and Prévot (1937), *Les Microbes Anaérobies*, Paris; Wilson and Miles.

ANAEROBIC SPORE TEST. (Stormy fermentation test.) *See* Butyric acid bacteria.

ANAEROGENIC. Producing anaerobic conditions.

ANAESTHESIA. Without feeling or sensation.

Ref.: Wright (1947), *Veterinary Anaesthesia*, London.

ANALYSIS. In the strict sense this term means the breaking down of a material into its constituents. It is commonly used in two senses: (i) qualitative analysis, the determination of the constituents of a substance, *e.g.* elements, radicles, etc.; (ii) quantitative analysis, the determination of the amount of each constituent present.

The word "analyst" is commonly used for the head of a dairy control laboratory. *See* Routine laboratory tests; Testing of milk supplies.

Refs.: General: Milk testing; LCDP; SMDP; Chemical: Mojonnier; Richmond; *AOAC;* Wright; Allport (1945), *Colorimetric Analysis*, London. *Bacteriological:* Chalmers; Cunningham; Wilson *et al.;* Demeter; House; *Agricultural:* Wright; *AOAC.*

ANILINE YELLOW. The commonest yellow aniline dye formerly used for colouring purposes in foods. Its use in dairy products is now forbidden.

ANIONS. Salts and certain other chemical compounds when dissolved in water dissociate into two or more electrically charged parts. Thus if an electric current is passed through such a solution, one part (ion or radicle) goes to the negative electrode and one to the positive. For example, in sodium chloride solution, the positively-charged sodium (Na) ions go to the cathode and so are called cations and the negatively-charged chloride (Cl) ions go to the anode and are called anions.

$$\text{Negative} \mid Na^{+} \leftarrow NaCl \rightarrow Cl^{-} \mid \text{Positive.}$$

ANNATTO. This natural colouring matter is commonly used for all coloured cheese in this country and also for butter. It is obtained from the fruit of the annatto tree, *Bixa orellana*, which is found native in many tropical countries and is cultivated in the West Indies, Brazil, and India. The seeds are covered with a yellow-red resinous material which is removed by extraction, or by maceration and fermentation followed by straining and evaporation of the water in the sun. The latter method yields a crude product known as " paste annatto ".

Extraction is usually carried out with a refined vegetable oil, such as rape-seed, and the product is then known as *bixen*. This solution can be added direct to cream in the churn as the annatto readily passes from one fat phase to another.

Annatto paste requires " working in " with butter, which leads to the danger of over-working. For cheese, an alkaline solution containing about 10 per cent. solids, of which only a small amount is actual colouring matter, is used, and this allows the even distribution of the pigment to both the casein and the fat. The oily " butter annatto " cannot be used for cheesemaking. This pigment is still used for dyeing oils as well as for butter and cheese, and for a wide variety of other products.

Properties. The pigment is called *bixin*, has the empirical formula $C_{25}H_{30}O_4$, and forms dark red rhombic crystals melting at 192° to 198° c. It has the following formula :

$$CH_3 . O . OC(CH=CH—C(CH_3)=CH)_2CH=$$
$$CH(CH=C(CH_3)—CH=CH)_2COOH$$

In commercial alkaline solutions the pigment exists as the potassium salt of *norbixin*, which is the free acid of *bixin*. The colour of this salt is mainly yellow, with a little red : as the *p*H of the solution is lowered, the intensity of the yellow falls and that of the red rises, especially between *p*H 6·0 and 5·7. It is readily soluble in chloroform and alcohol, and gives a deep blue coloration with sulphuric acid, a reaction which can be used to detect traces of annatto. The pigment is sensitive to light but resistant to both dilute acids and dilute alkalis. As the formula indicates, annatto is very susceptible to oxidation and is bleached by dilute hydrogen peroxide, and, rather slowly, by air. This latter reaction is catalysed by light. Like milk fat, annatto can act as a hydrogen donator or oxygen acceptor, *i.e.* it can be oxidised at the expense of certain weak oxidising agents. Thus methylene blue and annatto can bleach each other. Copper accelerates the oxidation of annatto by hydrogen peroxide, etc., and iron does so to a certain extent at alkaline reactions. Sulphydryl compounds may also act as oxidative catalysts. If protected from air, however, annatto is not affected by reducing agents such as hydrogen sulphide and sulphur dioxide.

Impurities. In addition to harmless substances of low pigment value, it has been reported that red lead may occur in commercial samples. Apart from the question of toxic effects, there is the danger of black discoloration in the cheese due to the formation of lead sulphide by hydrogen sulphide-forming bacteria. This impurity can readily be detected by passing sulphuretted hydrogen through the annatto solution.

Storage. According to Carrie annatto deteriorates more quickly in glass bottles than in steel drums. In the latter the loss is of the order of 10 per cent. in three years. For further information about annatto the reader is recommended to consult Barnicoat (1937), *JDR*, **8,** 61 ; Carrie (1938), *JDR*, **9,** 72, and Barnicoat (1946), *JDR*, **14,** 59.

Standardisation. The standardisation of annatto in cheese is not a straightforward matter, as the colour is affected by the fat and water content and the acidity of the cheese. In ordinary solution the measurement of annatto colour is easily performed with a suitable instrument such as a Zeiss-Pulfrich or Leitz photometer. Annatto obeys Beer's law, *i.e.* the intensity of colour by transmitted light is proportional to the concentration. If the Lovibond tintometer is used, however, the reflection of light from the glasses introduces an error which makes it appear that Beer's law is not strictly obeyed.

When we come to consider the colour of annatto in cheese, which is the practical criterion, various difficulties are encountered. Annatto in cheese is mainly in combination with the casein, *i.e.* it is in a different form from the pigment in simple alkaline solution. Further, it has been found that the initial concentration of annatto in milk is not a safe guide to the colour of the resultant cheese.

Different annatto preparations appear to vary in their ratio of red to yellow. Thus Barnicoat found 0·35, 0·16, 0·11, 0·14. 0·20, 0·38, and 0·17 as experimentally determined ratios. He suggests a standard of 4·0 yellow units, 0·4 red, and 0·1 neutral (Lovibond scale) for a one in ten thousand in N/10 sodium hydroxide solution. This gives a ratio of 0·1, which is rather different from the average, as pointed out by Carrie. Actually Barnicoat's figures varied from 1·3 to 6·1 yellow units and from 0·5 to 1·0 red.

Both the absolute figures and ratios are very variable, and in view of the fact that red is of greater importance in cheese colour than yellow, it may be suggested that in any assessment of annatto, more attention should be paid to the red component than to the yellow.

One possibility would be a compensating formula of the form : x yellow + A . y red units to indicate the effective colour in cheese, where A would be greater than 1 and could be determined experimentally by a comparison of scientific measurements and graders' scores. The best method of standardisation would seem to be in an artificial " cheese " composed of butterfat and casein at *p*H 5·5 and prepared under standard conditions.

ANOESTRUS. The period of sexual inactivity or non-mating. *See* Breeding; Milk Secretion.

ANTHRAX. A cattle disease of high mortality caused by *Bacillus anthracis*, a spore-forming aerobic organism. Milk secretion ceases early in the disease and the organism only passes into the milk in the latest stages of the disease.

Refs. : Miller ; Wilson and Miles.

ANTI-BACTERIAL SUBSTANCES IN MILK. *See* Lactenin.

ANTIBIOTICS. A general term for bactericidal substances produced by living organisms. They are summarised in Table An I.

TABLE An I

Organism	*Name*	*Chemical nature*	*Acting upon*
P. notatum . .	Penicillin	—	Most types, especially Gram +ve.
B. brevis . . .	Gramicidin	Polypeptide	Mainly Gram +ve.
B. brevis . . .	Tyrocidin	Polypeptide	Mainly Gram +ve.
P. aeruginosa (*B. pyocaneus*)	Pyocyanin	Pigment	Mainly Gram +ve.
Actinomyces sp. . .	Streptomycin		General.
A. antibioticus . .	Actinomycin	Polycyclic	All types.
Str. lactis . . .	Nisin	—	Mainly Gram+ve.

See Penicillin.

Refs. : Bailey and Cavallito (1948), *ARM*, **2,** 143 ; Duemling (1947), *Antibiotics*, New York ; Herrell (1946), *Penicillin and other Antibiotic Agents*, London ; Wilson and Miles; Stoltz and Hankinson (1953), *JMFT* **16,** 157; Overby (1954), *DSA*, **16,** 1 (review); Hirsch (1953), *SAB*, **16**, 100 (food preservation); Wessner (1953), *IDC*, **3**, 1121 (penicillin in cheese milk); Jacquet (1953), *IDC*, **3**, 1143; Hugo (1953), *LP*, **2**, 245 (assay); Kosikowsky *et al.* (1952), *JDS*, **35**, 533; Routien and Finlay (1952), *BK*, **16**, 51; Rowlands (1951), *SAB*, **14**, 7 (penicillin on K.Q.); Pratt and Dufrenoy (1948), *BR*, **12**, 79 (mechanism penicillin); Wilkowske and Krienke (1951), *JDS*, **34**, 1030 (penicillin on lactobacilli); Friedmann and Epstein (1951), *JGM*, **5**, 830 (nisin assay); Hirsch (1951), *JGM*, **5**, 208 (nisin); **4**, 70 (nisin assay); Hirsch and Wheater (1951), *JDR*, **18**, 193; Hirsch and Grinsted (1951), *JDR*, **18**, 198 (streptococci); Hirsch *et al.* (1951), *JDR*, **18**, 205 (inhibition of anaerobes); Hunter (1949), *JDR*, **16**, 39 (penicillin on streptococci); Bradfield *et al.* (1952), *JDS*, **35**, 51 (aureomycin on starters); Barbiro and Foster (1951), *JDS*, **34**, 1128, 1136 (streptococcal inhibitors).

ANTIBODIES. A name applied to any substance formed in the body to combat the toxic effect of bacteria (antigens). Colostrum is particularly high in antibodies, which are drained from the blood of the mother. *See* Immunity.

ANTI-FREEZE SOLUTIONS. Glycerine and ethylene glycol are commonly used:

% Glycerol (weight)	*Freezing point* °F	*% Glycol (volume)*	*Freezing point* °F.
20	23·4	12·5	25
30	14·9	17	20
40	4·3	25	10
50	– 9·4	32·5	0

ANTIGEN. Any substance which promotes the formation of antibodies in the blood of an animal, *e.g.* bacteria, bacterial toxin, certain proteins. *See* Immunity.

ANTI-OXIDANTS. The fat and lecithin in milk, and of course whole milk products, contain unsaturated fatty acids such as oleic and linoleic acid which are readily oxidised by the oxygen of the air, especially in the presence of catalysts such as traces of copper and the oxidising enzymes (oxidases or dehydrogenases). The intermediate or final stages of oxidation may produce certain chemical substances (aldehydes, ketones, and peroxides) which confer an unpleasant flavour on the product *e.g.* tallowiness, oxidised flavour, etc.

Various methods have been suggested for combating this fault, among them: (i) preventing metallic contamination, especially that of copper; (ii) heat treatment to destroy the oxidising enzymes or inactivate the active groupings in the fat and lipoids; (iii) addition of anti-oxidants to neutralise the oxidising systems. These fall into two groups (*a*) natural extractives such as those from the oat germ (*e.g.* Avenex) and (*b*) organic chemicals such as ethyl gallate and certain hydroquinones. *See* Auto-oxidation; Milk powder; Stability.

Refs.: Richmond; Davies; Sjöström and Larsson (1949), *IDC*, **2**, 368; Findlay *et al.* (1945), *JDR*, **14**, 165 (spray powder); Waite (1941), *JDR*, **12**, 178 (hydroquinone and oat flour); Lea (1938), *Rancidity in Edible Fats*, H.M.S.O.

ANTISEPTICS. Any substance which kills micro-organisms, but commonly applied to phenols, hypochlorites, hydrogen peroxide, etc. *See* Chlorine; Disinfection.

Refs.: McCulloch; Wilson and Miles.

APPEAL TO THE COW TEST. When a producer is accused of watering his milk on account of low fat or solids-not-fat, he may cause an " appeal to the cow test " to be made to justify his claim that his cows are actually giving milk of poor quality. Buyers are entitled to refuse milk below 3 per cent. fat or 8·5 per cent. solids-not-fat, even if genuine. *See* Adulteration; Freezing point test.

APPETITOST. *See* Cheese (p. 184).

ARABLE. This term means literally fit for ploughing or cultivation, but usually refers to land which is ploughed and produces arable crops, *e.g.* cereals, roots, etc. *See* Agriculture; Feeding.

ARACHIDIC ACID. $C_{19}H_{39}.COOH$ occurs in small amounts in milk fat and is found in the earth nut.

ARACHIDONIC ACID. The most important of the highly unsaturated fatty acids in butterfat $C_{19}H_{31}.COOH$.

ARAKAWA REACTION IN HUMAN MILK. The peroxidase reaction. *See* Enzymes.

AROMA. Aroma may be defined as that property of a material which affects the olfactory sense. Flavour consists of *taste* and *aroma*. The most important aroma constituents of dairy products appear to be as follows:

Fresh milk	Carbon dioxide, acetone bodies.
Heated milk	Hydrogen sulphide.
Soured milk	Diacetyl, acetic acid, substances associated with lactic acid.
Butter	Diacetyl, acetic acid.
Cheese	Volatile acids, ketones, esters.

See Cheese; Flavours.

Ref.: Moncrieff.

ARTIFICIAL CREAM. This term was formerly used in two ways, but its definition is now given as "an article of food which though not cream resembles cream, and contains no ingredient which is not derived from milk except water". The term "synthetic cream" (p. 1005) is now reserved for preparations utilising vegetable fats.

ARTIFICIAL INSEMINATION. *See* Agriculture; Breeding.

Refs.: Perry (1949), *IDC*, **1**, 639; Branton *et al.* (1952), *JDS*, **35**, 801; Feckheimer *et al.*, 808; Willett and Larson, 899; Schultze and Mahler, 906; Corley *et al.*, 963.

ASCOMYCETES. A class of fungi or lower plants which includes the moulds and yeasts.

ASCORBIC ACID. The chemical name for vitamin C. *See* Vitamins.

Ref.: Allan (1950), *JDR*, **17**, 54 (oxidation).

ASEPTIC. Free from living micro-organisms, spores, and viruses.

ASEPTIC CANNING. A system of canning in which sterilised foods are canned under aseptic conditions, *e.g.* in an atmosphere of live steam or in an atmosphere sterilised by ultra-violet radiation. The method is at present (1953) in its infancy but will probably become of great importance, especially for milk sterilised by new methods.

Refs.: Anon. (1953) *Austral. Food Manuf.* **22**, (11), 26.

ASEPTIC PRECAUTIONS. Methods used in bacteriology, especially in sampling, to avoid contamination by micro-organisms. They consist of: (i) flaming all implements, etc. in a Bunsen or alcohol flame; (ii) autoclaving or hot air sterilising of all glassware, etc.; (iii) quick manipulation and non-touching of other objects; (iv) various precautions to exclude dust, etc.

ASEPTICALLY-DRAWN MILK. Milk drawn from the udder under aseptic conditions (washing with hypochlorite, etc.). The use of a teat-syphon can lead to damage to the teat and should be avoided. Aseptically drawn milk is not sterile, as sometimes stated. In the healthy udder the colony count of the milk is usually less than 300 per ml., but if mastitis is present the count may be over 1000 per ml. *See* Abnormal milk; Mastitis.

ASH OF MILK. If milk is heated to a dull red heat to destroy all organic matter it leaves about 0·7 per cent. ash. This has the following composition:

	Per cent.
P_2O_5	21 to 29
K_2O	24 to 30
CaO	20 to 27
Cl	14 to 16
Na_2O	6 to 12
MgO	2 to 3

and Fe_2O_3, CO_2, etc.

Refs. Davies; Richmond.

ASPERGILLUS. A genus of mould (p. 750).

Refs.: Smith ; Thom and Raper (1945), *A Manual of the Aspergilli*, London.

ASPHALT. A bituminous complex of hydrocarbons found at the Dead Sea. It forms an excellent material for floors when suitably reinforced and is sometimes used for lining storage pits for whey.

ASSES' MILK. This, being very similar in chemical composition to human milk, is of especial medical interest. *See* Infant foods; Mammals.

ASSOCIATION, BACTERIAL. The interaction of different types of bacteria to produce conditions or chemical changes which would not occur with one type of bacterium only. Typical examples of interest in dairying are the destruction of acids and oxygen to allow other types of bacteria to grow. *See* Stability.

ASSOCIATIVE ACTION. A change which is brought about by the agencies of two or more factors, *e.g.* enzymes or bacteria.

ATMOSPHERE. *See* Air.

ATMOSPHERIC SHADE TEMPERATURE. This is of the greatest importance in the dairy industry (*see* Bacteriological grading of milk). It is commonly defined as the temperature in a well-ventilated box on the north side of a building. *See* National Milk Testing Scheme.

ATOM. The smallest particle of matter which can take part in a chemical reaction. *See* Element.

ATROPHY. A wasting away or deterioration of tissue, especially a gland.

ATTESTED HERDS. *See* Legal aspects ; Milk marketing.

Ref.: *Milk Production*, Reports Nos. 1 to 4, M.M.B.

AUSTRALIA.

Refs.: Ashton *et al.* (1949-52) *Dairy Farming in Australia* (4 vols.), Cmwth. Dpt. Com. Agric ; Hills (1952), *DSA*, **14**, 563; Macfarlane and Wiley (1949), *IDC*, **4**, 483.

AUSTRIA.

Ref.: Haunold (1949), *IDC*, **4**, 493.

AUTHORITIES CONTROLLING MILK.

Authorities and Other Bodies Controlling and Examining Milk

Authority or Worker	*Administered by*	*Function*
Sanitary inspector	Local authority	Control of condition of premises, utensils, etc.
Veterinary surgeon	Ministry of Agriculture through provincial centre (or in private practice)	Control of health of cows, especially in relation to T.B. treatment of mastitis, etc.
Dairy instructress	Ministry of Agriculture (N.A.A.S.)	Education of producer in methods of clean milk production, etc.
Joint Milk Quality Control Committee	Jointly by Central Milk Distributive Committee and M.M.B.	General control of bacteriological quality of milk as produced.
Medical Officer of Health	Local authority	Protection of consumer. Condemnation of unsafe milk.

See Legal aspects ; Milk (Special Designations) Orders ; National Milk Testing Scheme ; Pasteurisation.

AUTOCLAVE. A strong vessel capable of withstanding pressures of several atmospheres and used for sterilising bacteriological media, equipment, and also milk and other liquid foods. The higher the temperature required the higher is the corresponding pressure (Table Au I).

TABLE Au I

Temperature (° c.)	*Pressure* (*atmospheres*)
120	1
134	2
144	3
152	4
159	5

See Media; Sterilised milk.

Refs.: Thiel *et al.* (1952), *SAB*, **15**, 53; White (1953), *LP*, **2**, 590 (pressure cookers).

AUTO-OXIDATION OF FAT. This phenomenon is of special interest to the manufacturer of milk powder and butter. The chemical changes in fat which lead to off-taints are loosely referred to as " rancidity " ; this term is sometimes used specifically for hydrolytic changes, *e.g.* glyceryl butyrate → glycerol + butyric acid, and the term " tallowiness " used for the oxidative changes. The two types of reaction are closely inter-linked. In addition other chemical substances which in practice are always present with fats, *e.g.* aldehydes, proteins with sulphydryl groupings, etc., also undergo oxidative changes in the presence of atmospheric oxygen. In the early stages the condition may be described as " flatness " or " slightly oily ". Once started, however, the change proceeds rapidly, the fat becoming pronouncedly " cardboardy ", " tallowy ", " oxidised ", and finally indisputably rancid. The chemical reaction is autocatalytic, *i.e.* the rate of change increases progressively up to a point. The rate is considerably influenced by traces of certain substances, whether these accelerate the reaction, *e.g.* copper, or retard it, *e.g.* hydroquinones and amines. The former activate the oxygen and the latter accept it, *i.e.* they are themselves oxidised and so spare the fat by being destroyed themselves.

Auto-oxidations also may accelerate the oxidation of other substances normally fairly stable to oxidation by atmospheric oxygen, *e.g.* less labile fatty acids or their esters. Auto-oxidation may also result in polymerisation.

Like all S-curved reactions, auto-oxidation is characterised by three stages: (i) a period of slow change ; (ii) rapid deterioration, and (iii) dying away.

It was formerly thought that the induction period was due to the slow accumulation of a product of the reaction which itself acted as a catalyst, *e.g.* a fat or lipoid peroxide. The present view is that this lag is due to the presence of inhibitors or anti-oxidants as impurities and that the reduction of the lag period observable when a small quantity of the oxidised product is added is due to the oxidation of the inhibitor.

Many factors can accelerate the oxidation of fats the most important being: (i) temperature ; (ii) light and other radiation ; (iii) oxidising agents such as ozone, peroxides including peracids, nitro compounds, etc.; (iv) traces of certain metals, *e.g.* copper ; (v) oxidative enzymes.

Temperature. The normal temperatures of cold storage usually so depress the rate of oxidation, that deterioration is no longer an anxiety. For example, butter is held at 12° F. during enshipment from Australia and New Zealand. Higher temperatures lead to rapid deterioration, the coefficient being the usual one for chemical reactions, *viz.* 2 to 2·5 per 10° c. rise.

Light. Radiation acts by accelerating the oxidation of the unsaturated fatty acids but does not produce rancidity in the *complete* absence of oxygen. Absorption is greatest in the near ultra-violet and is due to the sterols and fat soluble vitamins usually present. Winter sunlight and reflected sunlight, which are much poorer in ultra-violet than direct summer sunlight, are less effective in promoting rancidity.

Davies ((1934), *JSCI*, **53**, 148 T ; (1937), *FM*, **12**, 41) found that thin, clear glass was without effect; colourless, pale blue, pink, orange, and lemon Cellophanes and transparent paper had little effect; heliotrope, light green Cellophane and greaseproof paper gave some protection; and deeply coloured Cellophanes, irrespective of the colour, gave considerable protection.

Oxidising Agents. The only point of practical interest is the possible use of ozone for deodorising stores and ships' holds.

Metals. Copper is easily the most powerful, the order being copper, manganese, iron ($Fe^{\cdot\cdot\cdot}$), vanadium, chromium, nickel, zinc, aluminium, lead, and tin ($Sn^{\cdot\cdot\cdot\cdot}$). (*See* Flavours.)

Enzymes. These may be present in the milk or be produced by micro-organisms. Heat treatment may be beneficial by destroying both.

Refs.: Davies; Rogers; Lea (1938), *Rancidity in Edible Fats, DSIR* "Food Invest. Spec. Rep.", No. 46; Pont (1952), *JDR*, **19**, 316; Krukovsky (1952), *JDS*, **53**, 21 (origin oxidised flavours); Dunkley and Jennings (1951), *JDS*, **34**, 1064 (thiobarbituric acid test); Forster and Sommer (1951), *JDS*, **34**, 992; Keeney and Doan (1951), *JDS*, **34**, 713, 719, 728; Paton and Kurtz (1951), *JDS*, **34**, 669; Stull *et al.* (1951), *JDS*, **34**, 80, 181, 187; Krukovsky *et al.* (1950), *JDS*, **33**, 791; Schmalfuss (1947), *M*, **2**, 335 (extensive bibliography); Mummery (1947), *JDR*, **15**, 55 (Schibsted aldehyde test); Hills and Thiel (1946), *JDR*, **14**, 340 (fat peroxide estimation); Smith (1939), *JDR*, **10**, 294 (rapid estimation of peroxide value); Wiley (1939), *JDR*, **10**, 300 (oxidation of butterfat in cold storage).

AUXILIARY DAIRY. A name applied to small separating stations in Ireland where milk is separated and the cream sent to a central butter factory.

AVAILABLE CHLORINE. *See* Chlorine.

AVÉ-LALLEMANT METHOD. This method is a modification of König and Hart's method of determining the baryta value of fat, and can be used to detect adulteration of butter. If b = insoluble soap fraction and c = the soluble as mg. BaO per g. fat, then $b - (200 + c)$ is nil or negative for pure butter but positive if the butter is adulterated. Values for butter range from 0 to −24, for coconut oil from 39 to 45 and for lard from 47 to 50.

Ref.: Avé-Lallemant (1907), *A*, **32**, 382.

TABLE AvC 1

Average Values for Five Year Periods in England from 1900 to 1950

Period	*No. of samples*	*Unweighted* average fat	*Unweighted* values S.N.F.	*Weighted* average fat	*Weighted* values S.N.F.
1900–05	3,415	3·61	8·61	3·61	8·61
1906–10	6,511	3·51	8·72	3·53	8·70
1911–15	21,686	3·60	8·78	3·60	8·78
1916–20	27,860	3·65	8·79	3·66	8·83
1921–25	34,448	3·68	8·87	3·65	8·91
1926–30	43,695	3·65	8·83	3·70	8·83
1931–35	61,160	3·68	8·84	3·67	8·81
1936–40	93,376	3·69	8·82	3·65	8·79
1941–45	90,078	3·71	8·77	3·64	8·76
1946–50	139,661	3·64	8·75	3·62	8·74

These figures indicate that the S.N.F. values have increased from 1900 to 1921–25 and since fallen.

There appears to have been an increase of about 0·25 per cent., and since 1921–25 a fall of about 0·1 per cent. The fat appears to have increased slowly up to 1941–45 and since then fallen.

Those areas showing a fall in composition in recent years (north western, midland, and south) have contributed a greater number of results (17 out of 28 authorities) than those regions which have shown no changes in composition.

AVERAGE COMPOSITION OF MILK. The composition of bulk milk (mainly from Shorthorn and Friesian cows) as sold to the public varies slightly, being rather poorer in fat from April to June and in solids-not-fat from February to April. The average is about 3·7 per cent. fat and 8·7 per cent. solids-not-fat. Areas where other breeds predominate will have higher values, *e.g.* Scotland (Ayrshire cows) and West Cornwall (Guernsey cows). The average composition of milk in this country appears to have fallen in respect of solids-not-fat and possibly also fat during the last 20 years, owing to the increase in the number of Friesian cattle and to breeding for quantity without regard to quality. Davis (1952) has published a survey of data for consumer milk over the period 1900–50, The results are summarised in Table AvC 1. *See* Abnormal milk; Composition, factors affecting; Quality payment.

Refs.: Davis (1952), *A*, 77, 499; Provan '(1949), *IDC*, **2**, 217; Provan and Jenkins (1949), *JSDT*, **2**, 88; Kay (1947), *JRSI*, **67**, 515; Davies; Richmond.

AVITAMINOSIS. A condition of vitamin deficiency. *See* Nutritive value; Rickets; Scurvy; Vitamins.

AYRSHIRE COWS. This breed is the most popular of dairy breeds in Scotland and is growing in popularity in England. They are particularly suitable for hilly country and light land and are highly resistant to adverse climatic conditions. The milk is slightly richer than Shorthorn milk and the fat globules are small. For this reason the milk is particularly good for cheesemaking. The disadvantages of the breed are that the animals have no beef value and the horns are rather long. Some experts consider that the teats are rather short for convenience in milking. *See* Breeding; Quality payment.

Ref.: Paterson (1951), *JSDT*, **5**, 17 (history).

BABCOCK TEST. *See* Fa .

BABY FOODS. *See* Infant foods.

BACILLUS. (i) In a general sense a rod-shaped micro-organism ; (ii) in the sense of modern bacteriological nomenclature an aerobic spore-forming genus of the true bacteria. Type species, *B. subtilis*, the " hay bacillus ". *See* Classification.

Refs.: Bergey; Knight and Proom (1950), *JGM*, **4**, 508; Gibson (1944), *JDR*, **13**, 248.

BACKSTEIN. *See* Cheese, p. 184.

BACTERIA. This term means strictly rod-shaped micro-organisms only but is used in a loose sense to include all micro-organisms, excluding, however, yeasts and moulds. *See* Classification.

Refs.: Bergey; Wilson and Miles; Bisset and Moore (1952), *Bacteria;* Werkman and Wilson (ed.) (1951), *Bacterial Physiology;* Porter (1946), *Bacterial Chemistry and Physiology*, New York; Hinshelwood (1946), *The Chemical Kinetics of the Bacterial Cell*, Oxford; Dubos (1945), *The Bacterial Cell*, Cambridge, Mass.; Stephenson.

BACTERIAL ANTAGONISM. The inhibitory action of some bacteria on others. *See* Antibiotics.

Refs. : Waksman (1945), *Microbial Antagonisms and Antibiotic Substances*, New York ; Hirsch (1946), *SAB*, p. 26 (inhibitory streptococci).

BACTERIAL COUNT. (i) In a loose sense the result of any test which estimates the number of bacteria present, *e.g.* plate count, microscopic count, methylene blue test, etc. (ii) In a stricter sense the enumeration of the numbers present by the plate count or microscopic count or, less commonly, the Frost little plate method. It is not possible to say which is the best method without defining the conditions of testing and the type of information required. *See* Bacteriological grading of milk ; Methylene blue test ; Microscopic count ; Plate count ; Resazurin tests ; Roll tube.

Refs.: Chalmers ; Cunningham ; Wilson *et al.* ; Barkworth (1944), *D* (9) 26, (10) 16, (11) 11, (13) 13 ; (1945), (3) 89, (5) 15, (11) 51.

BACTERIAL DISSOCIATION.

Ref. Braun (1947), *BR*, **11**, 75.

BACTERIAL GENETICS.

Ref.: Luria (1947), *BR*, **11**, 1.

BACTERICIDAL. This term is applied to any substance or condition which has a killing effect on bacteria. In dairying the most important bactericidal agencies are heat (pasteurisation), caustic alkalis (detergents in bottle-washing), chlorine (utensils and water), and ultra-violet light, now being developed for pasteurising milk and sterilising air. A recent development is the use of quaternary ammonium compounds (p. 879) for bottle-washing detergents and also for cleaning crockery and drinking glasses. *See* Chlorine ; Cleaning and sterilising ; Detergents ; Disinfectants ; Sterilisation.

Refs.: McCulloch ; Wilson and Miles.

BACTERICIDAL SUBSTANCES IN MILK. Milk contains variable amounts of substances which retard the growth of bacteria, or appear to do so. Various workers claim to have proved the presence of agglutinins, opsonins, and other immune bodies. Whatever their nature, it is generally recognised that active proliferation does not take place for a certain period after milk leaves the udder, 4 to 6 hours at 37° and up to 24 hours at low temperatures (Heinemann). Further,

RAW MILKS

(1) Ten minute resazurin test at 37° C.

Disc. no.	*Mean values*					
	Acidity [2] %	pH [1]	*Plate count* [2]	*Clump count* [2]	*MB* 37° [1]	*MB* 37° [2]
6*		6·55				
5		6·49			1½ hrs.	
4	0·16	6·42	7 × 10^6	22 × 10^6	40 mins.	34 mins.
3	0 17	6·39	46 × 10^6	40 × 10^6	30 mins.	27 mins.
2	0·18	6·26	38 × 10^6	36 × 10^6	23 mins.	18 mins.
1	0·20	—	170 × 10^6	20 × 10^6	17 mins.	12 mins.
½	0·21	—	1202 × 10^6	76 × 10^6	15 mins.	7 mins.
0*	0·34	6·10	1445 × 10^6	100 × 10^6		3 mins.

Disc. no.	*Mean values*			
	10 *min. res.* 18 [1]	1 *hr. res.* 18° [1]	*K.Q.* (*COB*) 18° (*hr.*) [3]	[5]
6*	6	6	19·1	40
5	5 9	4	18·8	28
4	5·2	2 +	11·3	19
3	4·2	1 +	10·6	16
2	3 7	1 +	8·2	13
1	—	—	—	—
½	—	—	5 3	—
0*	2·3	0		—

* Note that disc 6 is an indefinite group including the highest grades, disc 0 similarly includes the dirtiest milks.

(2) Methylene blue test at 37° C.

Reduction time (*hr.*)	*Plate count* [1]	*Acidity* %	*K.Q.* (*COB*) 18° (*hr.*) [5]
9	1,400		49
8			47
7	15,500		
6			35
5	178,000		
4½		0·155	30
4		0·155	
3½		0·155	
3	1,995,000	0·16	
2½		0 16	20
2		0·165	
1½		0·17	
1	22,400,000	0·175	
¾		0·175	12
½		0·19	
¼		0·24	

References on next page.

Methylene blue at 18° (*hr.*)	*K.Q.*(*COB*) 18° (*hr.*)[5]	*Resazurin to disc O at* 18° (*hr.*)	*K.Q.* (*COB*) 18° (*hr.*)[5]
46 and over	69	46 and over	59
31–45	56	31–45	46
26–30	44	26–30	40
21–25	43	21–25	34
16–20	34	16–20	33
11–15	32	11–15	28
6–10	28	6–10	20
under 6	14	under 6	12

Refs.: [1] Barkworth *et al.* (1943), *DI*, **8**, 215; [2] Thomas and Phillips (1942), *SAB*, p. 22; [3] Davis *et al.* (1943), *DI*, **8**, 23 (in summer); [4] Barkworth (1945), *DI*, **10**, 40 and 120; [5] Davis *et al.* (1944-45) (unpublished data).

the bacteria in the milk inside the healthy udder do not usually exceed 300 per ml. (*see* Mastitis). It is probable that milk, especially colostrum, contains sufficient antibodies to be of significance for the suckling animal.

Refs.: Morris and Edwards (1950), *JDR*, **17**, 253 (against coli); Marrack (1947) *Brit. Med. Bull.*, **5**, 187.

BACTERIOLOGICAL EQUIVALENTS. It is dangerous to try to state the value of one bacteriological test for milk in terms of another, because so many factors have to be considered, *e.g.*: (i) type of milk; (ii) season of the year; (iii) prevailing temperatures; (iv) error of methods concerned; (v) types of bacteria present. The above tables (pp. 63-64) should be used *only as a guide* to the order of result which may be expected.

BACTERIOLOGICAL GRADING OF MILK. The first tests in the history of the bacteriological control of milk were taken practically entirely from medical bacteriology, and for many years the plate count and coliform test were used universally. It was gradually realised that although the plate count and coli tests were probably unexcelled as measures of cleanliness in production, they frequently failed to give a reasonably accurate assessment of keeping quality. The last few years in dairy bacteriology have been characterised by a gradual swing of the pendulum away from the plate count to keeping quality aspects. There is a danger that in evaluating tests such as the resazurin and methylene blue tests in terms of keeping quality, we may come to regard keeping quality as some absolute property of a milk when the fact is that keeping quality is quite as arbitrary a yardstick as any other.

Those properties of milk of interest to the consumer are set out in Table BG I. It is obvious that the non-technical consumer is not aware of all these aspects of milk; the only property which he can detect is the presence of any taint. From the public health point of view, the outstanding property is freedom from pathogenic organisms. Those who are familiar with the bacteriological properties of milk will agree that ideally milk should be free from pathogenic organisms, derived from a disease-free udder, produced by clean methods, and should have

TABLE BG I

	Factors	*Effect on K.Q.*
Hygienic Quality	Pathogenic organisms	Nil or slight
	Mastitis	Variable
	Cleanliness in production:	
	(*a*) Visible dirt	Very slight
	(*b*) Bacterial contamination	Considerable
	Subsequent contamination	Considerable and variable
	Temperature	Considerable

a low bacterial count. Finally, temperature is important because at any time it largely governs the behaviour of the milk during the subsequent few hours.

Cleanliness in Production. There is no one test which will measure all these aspects. Moreover, their effect on keeping quality is very variable (Table BG 1). The measurement of cleanliness in production is probably best made by a plate count and coliform test as soon after production as possible. There is still much confusion in the industry between *visible dirt*, as measured by a sediment test, and bacterial contamination, or what is sometimes called *invisible dirt*. The sediment test as applied at the creamery, which is a measure of mechanical dirt, *e.g.* cow hairs, cow faeces, pus cells, soil, etc., shows practically no correlation with keeping quality or any of the tests used indirectly to measure keeping quality. Very bad sediment tests may be associated with milk of good keeping quality, and this observation may be related to the fact that fresh bovine faeces may not only have no effect on keeping quality but may even improve it. Aged faeces invariably produced rapid deterioration in keeping quality.[1]

What is Keeping Quality ? Until recently keeping quality was arbitrarily measured by a procedure which involved holding a sample of milk at a temperature of 15·5° C. and testing every six hours by smell, taste, and clot-on-boiling test.[2] It is evident that there are many factors which can affect a keeping quality test, some of which have only recently been recognised (Table BG II). Obviously the most important point to settle is the determination of the end-point. We have no absolute criterion for this. Smell and taste are highly subjective and it is questionable whether they should be considered as end-points for scientific tests. There remain two other tests which can both be determined objectively and are accepted in the industry as indicating the end of the life of a milk beyond dispute. They are (i) the clot-on-boiling test and (ii) a measure of acidity. The clot-on-boiling test has the big advantage that there is an indisputable end-point, while the measurement of acidity involves an arbitrarily decided end-point. In practice these end-points give rather similar results, and since the deterioration of milk is largely a question of souring in warm weather, there is a considerable case for adopting an arbitrarily decided increase in acidity as an end-point in the keeping-quality test. For example, milk usually has an initial acidity of 0·14 per cent. lactic acid and usually clots on boiling at an acidity in the region of 0·24 per cent. lactic acid. A very convenient increase to adopt as a measure of keeping quality therefore would be one of 0·1 per cent. lactic acid. An acidity basis, however, completely ignores sweet curdling. This fault, like undulant fever, probably occurs much more often than is recognised. With the general increase in the cleanliness of the milk supply and the trend towards universal pasteurisation, it is likely that the importance of sweet curdling as an economic fault will increase. It is therefore probably unwise to adopt an end-point which ignores a fault which may have very large economic proportions.

TABLE BG II

FACTORS AFFECTING DETERMINATION OF KEEPING QUALITY

(1) Frequency of testing.
(2) End-point selected (smell, taste, or clot-on-boiling or combination of these).
(3) Temperature at which samples held.
(4) Agitation (degree and frequency).
(5) Oxygen tension of sample.

The clot-on-boiling test has two very great advantages: (i) an indisputable end-point, and (ii) the fact that it includes not only the end of the life of milk due to souring but also the end of the life of milk when it is due to sweet curdling. Other tests which may be regarded as variants of the clot-on-boiling test are the clot-at-room-temperature test, which involves holding the milk at room temperature or at a defined temperature, *e.g.* 18° C., until it clots,[3] and the alcohol test, in which equal volumes of the milk and a known strength of alcohol, *e.g.* 68 per cent. V/V are mixed together.

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[1] Davis and Phillips (1944), unpublished data.

[2] Min. Agric. (1932), *Bull.* 46, H.M.S.O.

Temperature of Test. The second most important factor in measuring keeping quality is the temperature of the test. It may be noted that these tests were formerly carried out at 15·5° C., but, largely as the result of experiencing difficulty in maintaining water baths at this temperature in hot weather, a temperature of 18° C. was suggested a few years ago[4] and this is now finding general favour. There is a further trend in some quarters to adopt 22° C. as a standard temperature for the obvious reason that it is more easy to maintain thermostatically, as water supplies may rise above 18° C. in hot weather, and it gives a quicker result and a sharper end-point, especially in dye reduction tests. But from the economic angle we have to recognise the fact that, with the increase in the efficiency of our methods of handling milk and the gradual trend towards refrigeration not only in the dairy industry but in the home, the temperature at which milk is held tends to become lower instead of higher. We are, therefore, raising the temperature of our keeping-quality tests while at the same time the temperature at which milk is held in practice is tending to fall. Although there is a fairly good correlation between the results of keeping-quality tests carried out at 15·5°, 18°, and 22°C. there is some scatter, and it is evident that the r value (correlation coefficient) of any test which is studied as an indirect measure of keeping quality will be affected by the temperature at which the keeping-quality test is carried out. This aspect has received practical confirmation in the work carried out by the mobile laboratory of the N.I.R.D. in South Wales, where it was found that some producers' milks gave good grading results when held at atmospheric temperature, but failed badly when held at 18° C.[5] The choice of temperature then will affect different milks in different ways. If we agree to get as closely to practical conditions as possible, we have to consider the fact that monthly mean atmospheric temperatures range from about 4° C. in winter to about 17° C. in summer (Table BG III). The best all-the-year-round temperature would thus be about 10° C., but not only would this be difficult to maintain in summer, but the results would be quite misleading. If we agree to adopt one temperature throughout the year, 18° C. appears to be justified on the grounds that it is at the upper end of the atmospheric temperature range, and a milk which " stands up " to this temperature will be most unlikely to fail at lower temperatures.

TABLE BG III

Month	*Mean temp.:* 1841–1905 ° C.
January	3·7
February	4·2
March	5·5
April	8·5
May	11·8
June	15·2
July	17·0
August	16·5
September	14·0
October	10·0
November	6·4
December	4·4

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[3] Davis and Ward (1944), *SAB*, p. 32.

[4] Davis and Watson (1942), *Milk Ind.*, Feb., p. 37.

[5] Davis, Wilby, Phillips, Davies, M., Davies, E. A., Lewis, B., and Reece, B. (1943-44), unpublished data.

Correlation between Tests. It has been found that the correlation between the end-point based on smell and on Bulletin 46 [2] (*i.e.* when first condemned on smell, taste, or clot-on-boiling) is very high. The correlation for taste and Bulletin 46 is also practically identical, but between clot-on-boiling and Bulletin 46 there is a wider scatter. This indicates that the predominating end-points in the Bulletin 46 procedure are taste and smell. We know that milks are often condemned on one of these before reaching the clot-on-boiling point. It has also been found that the correlation between the clot-on-boiling end-points at 15·5°, 18°, and 22° C. is fairly good, except between the extreme temperatures.[6] Moreover, when we study the correlation between the various indirect tests of keeping quality such as dye reduction tests, and keeping quality as measured by various end-point techniques, we find the closest relationship between the dye-tests and the clot-on-boiling end-point. This is what might be expected as the predominating factors in both dye tests and the clot-on-boiling test are acid-producing organisms. (Table BG IV.)

A further factor in the keeping-quality test is agitation, and the importance of this was realised when it was found that the non-disturbance of a sample in a filled bottle could be the cause of an appreciable increase in keeping quality.[7] The oxygen tension appears also to be a factor because most organisms in milk are facultative anaerobes and their growth will be accelerated by more aerobic conditions.

If we accept the contentions here put forward—namely, that keeping quality is as much an arbitrary property of milk as any of the other bacteriological aspects —it is logical to adopt an arbitrarily decided definition of keeping quality for the purposes of evaluation of tests. The following definitions are therefore tentatively proposed.

(1) ***Absolute keeping quality.*** This is defined as the time required by the milk to reach the clot-on-boiling stage when it is transferred to a water bath at 18° C. within three hours of production.

It will be obvious that this measure will involve sampling at the farm and will not be comparable with commercial conditions, especially in winter when mean temperatures are very much below 18° C. (Table BG III).

Reasons have already been given why no temperature compensation scheme can ever become universally applicable,[3] but we have to recognise the fact that, other things being equal, milk has a much better keeping quality in winter than in summer. For grading purposes, therefore, a second definition is produced.

(2) ***Grading keeping quality.*** This is defined as the time required to reach the clot-on-boiling stage when the milk is transferred to a water bath at 18° C. 25 ± 1 hours after production. This definition is mainly a utilitarian one in that it permits of sampling at the point of first delivery and enables either a.m. or p.m. milks to be treated.

Neither of these procedures will be of use for assessing the actual commercial keeping quality, which is as much a function of season and atmospheric temperature as of conditions of production. We may, therefore, find a use for a definition of *commercial* or *retail* keeping quality.

(3) ***Commercial or retail keeping quality.*** This is defined as the time required to reach the clot-on-boiling stage when the milk is held at atmospheric temperature from the time of production.

Irrespective of what criteria we agree to adopt as a measure of keeping quality, it is essential to use a standardised technique for this purpose. It has recently been realised that agitation and aeration can appreciably affect the result. It is therefore necessary to standardise these variables. There are, broadly speaking, two methods of doing this: (i) To have a large container, *e.g.* a pint bottle, half

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[6] Davis, Jones, V. E., Newland and Wilby (1944-45), unpublished data.

[7] Davis, Newland and Wilby (1945), *DI*, **10**, 182.

TABLE BG IV

Correlation between K Q Defined in Various Ways, and Dye Reduction Tests

(Davis, Jones, Newland and Wilby (1949))

						K Q of milk		
						Up to 50 hr	Over 50 hr	Overall
1	C O B	18	v	K Q (Bull 46)	18		-	- -
2	K Q (Bull. 46)	18	v	Condemned on smell	18	-	+ -	- - -
3	,,		v	,, taste	18	-	- -	- - - +
4	,,		v	K Q (Bull 46)	22	-		- -
5	,,		v	,,	15.5		- - -	
6	K Q (Bull 46)	22	v	,,	15.5		- -	-
7	C O B	18	v	C OB	22		-	-
8	,,	18	v	,,	15.5	-	- - - - +	- - - -
9	,,	22	v	,,	15.5	-	-	- -
10	,,	18	v	M B	37.5	+ -		- -
11	,,		v	M B	18	-	-	- +
12	,,		v	1 hr resazurin	37		-	-
13	,,		v	3 hr resazurin	22			-
14	,,		v	,,	18	-	-	-
15	,,		v	,,	15.5	-	-	- -
16	,,		v	time to disc 4	37.5		-	- -
17.	,,		v	,,	22	-	-	-
18			v		18		-	- -
19	,,		v	,,	15.5		-	- -
20	,,		v	time to disc 2	37.5	-		- -
21	,,		v	,,	22		- -	- - -
22	,,		v	,,	18	- -	-	- - -
23	,,		v	,,	15.5	-	- - -	- - - -
24	,,		v	time to disc 0	37.5	-	-	- -
25	,,		v	,,	22	- -	- -	- - -
26	,,		v	,,	18	-	+ - -	- - -
27	,,		v	,,	15.5		- - -	- - - -

Dye tests applied 24 hr after production Keeping qualities from time of production

Code– excellent v v good + – v good – – – good – – – +
f good fair – moderate +

full at the beginning of the test, and to shake by a standardised procedure every four hours and withdraw, say, 10 or 20 ml. aseptically. Such a procedure would be sound from the scientific point of view, but it cannot be claimed that such conditions are comparable with those obtaining in commercial practice, as milk is not normally violently shaken up every four hours. Moreover, in commercial practice, milk is frequently held in large containers where the degree of aeration must be very small, *e.g.* in tankers and in churns. (ii) An alternative method would be to fill out the sample after an initial thorough mixing in test tubes or boiling tubes in 10 or 20 ml. quantities, to hold all these tubes in a water bath at the agreed temperature, and then use one entire tube for each test every four hours. The adoption of a four-hour interval for testing is suggested as the best practical compromise for the problem. If these intervals are timed to coincide with 1 a.m. and 5 a.m. it enables one worker to do a night reading and then go to bed, and another worker to get up early for the 5 a.m. reading after having had a night's rest. The adoption of a shorter interval, *e.g.* three hours, involves workers doing all-night duty which is frequently difficult to arrange, and there is here the important aspect that when workers are tired the results may not always be as good as they would be when the workers are fresh.

Development of Testing Methods. Our methods of testing milk do not appear to have recognised the fact that in the last 50 years there has been a virtual revolution in the methods of handling milk before it reaches the consumer. Originally milk was sold raw, unmixed with other milks and mostly consumed within 24 hours of production. The problem of supplying the consumer in this country is now largely a problem of supplying a dense population. Half of our population lives in towns of over 100,000 inhabitants. A very considerable proportion of milk is now mixed with other milks, brine-cooled, sent some distance, pasteurised, re-cooled, and sold to the consumer some days after its production. It is only logical, therefore, that our methods of testing should be brought into line with the commercial treatment of the milk.

TABLE BG V

UTILISATION OF MILK IN ENGLAND AND WALES IN 1938 (*See also* p. 1116)

29 *per cent. of milk was manufactured as follows*

	1,000 *gallons*	%	*Output (cwt.)*
Butter	84,198	28	300,700
Cheese	58,572	20	522,100
Condensed milk	68,301	23	2,439,300
Condensed milk (export)	8,863	3	—
Milk powder	14,284	5	168,000
Fresh cream	47,283	16	305,100
Tinned cream	8,968	3	124,600
Other products	5,416	2	—

A further difficulty arises from the fact that not all milk is utilised in the same way (Table BG V). In 1938 just over 70 per cent. of our milk was consumed liquid and nearly 30 per cent. manufactured. From the commercial aspect the buyer is naturally interested in the behaviour of the milk from the point of view of its utilisation, and there at once arises a grave difficulty from a bacteriological control point of view, in that the properties required vary considerably according to the method of utilisation. This is illustrated in Table BG VI, where it will be seen what a wide range of bacteriological properties are required by different types of manufacture. In some circumstances a certain bacteriological quality may be desirable for one type of manufacture and undesirable for another. Now it will be obvious that it is impossible in practice to adapt methods of testing or standards according to the method of utilisation. For one thing, the method of utilisation is highly variable and one can never be sure from day to day as to which one will be used for any particular milk supply. We must therefore adopt one yardstick for all milks, otherwise the problem becomes unsolvable.

TABLE BG VI

ECONOMIC ASPECTS

Method of utilisation	*Types*		
	To be avoided	*Of no consequence*	*Desired*
Raw	1. Acid-producing 2. Rennin-producing 3. Taint-producing (types vary according to temperature at which milk held)	Inert	1. Inert types inhibitory to acid-, rennin-, and taint-producing types 2. Bacteriophages (?)
Pasteurised	Thermoduric, especially if acid-, rennin-, and taint-producing	1. Inert 2. Thermolabile	
Sterilised	Spore-formers, especially if taint-producing	Non-spore-formers	
Cheese	1. Taint-producing 2. Types inhibitory to acid-formers		1. Acid formers * 2. (?) certain flavour-producing types
Butter	Types producing taints in fat and curd		Acid- and aroma-producing types *
Condensed	1. Certain yeasts 2. Certain moulds 3. Rennin-producing (?)		
Evaporated	Spore-formers	Non-spore-formers	
Milk powder	Thermoduric types producing oxidative-lipolytic changes	Thermolabile	

* Sometimes.

One method of approach is to recognise the fact that no attempt at actual bacteriological assessment will ever be accepted by all concerned without dispute. If we are prepared to accept the constitution of hygienic quality as laid down in Table BG I, we can proceed to discuss the relative value of any one test or combination of tests for the factors which we accept as constituting the complex " hygienic quality ". We may rule out of the question the test for the presence of pathogenic organisms on account of technical difficulties. The obvious practical solution to the problem is to adopt universal pasteurisation or some similar treatment and to take the utmost precautions to prevent subsequent contamination. Of the remaining factors *bacterial population* and *keeping quality* are suggested as the most important. In other words, neither milk of high bacterial content but good keeping quality, nor one of low bacterial content but poor keeping quality, can be accepted as satisfactory. If we accept this the logical procedure is to attempt to find one test which will cover both or to be prepared to adopt two tests: (1) the most accurate practical test for keeping quality and (2) the most accurate practical test for bacterial content. The importance of differentiating between these two has been shown in sharp relief in the last few years by the intensive work on the resazurin and methylene blue tests. The resazurin test as a new test has naturally been the subject of much criticism, and various workers have brought forward instances where milk may have a good resazurin result but a high bacterial count and vice versa. It must be recognised, however, that the resazurin and methylene blue tests keep very closely together except in those cases where the milk has a very high cell content, *e.g.* over a million cells per ml. Further, one can compare any two tests and always find a milk which will give a good result by one test and a poor result by the other.

It is now generally accepted that milk can be produced under very dirty conditions in winter and, although giving a high plate count, *e.g.* over a million, yet have a good keeping quality, and give good results by dye-reduction tests. This is, of course, largely a temperature effect. It is therefore impossible to " pull up " such a producer by any of the usual keeping-quality tests. It is necessary to have recourse to special expedients, *e.g.* : (i) An extended temperature compensation scale in a dye test. (ii) Holding the sample for a period, *e.g.* eighteen or twenty-four hours, at an artificially elevated temperature, such as 18° C. (iii) Using a test which measures bacterial numbers, such as the plate count or direct microscopic count.

Against (i) it has been stated that when the incubation period is extended beyond two hours the cell effect becomes the predominating factor in the resazurin test, but adequate experimental evidence on this point is lacking. It is, however, true to say that the colder the weather the more quantitatively important the cell effect becomes. The latter is most noticeable in the early part of the test, and in a long time test, *e.g.* three to five hours, in cold weather it may be assumed that the final reducing effect (if any) is due to relatively small numbers, initially, of powerfully reducing organisms. A more serious criticism is that a test at 37° C. after some hours may have little relation to what the behaviour of the milk would have been in the region of 0° C.

(ii) is a possible solution, but would require a special juggling with the temperature compensation scheme.

The adoption of (iii) would *ipso facto* be a distinctly unfortunate criticism of our dye-reduction tests. The producer so down-graded would assert that the bacteriologist could not criticise his milk on the score of keeping quality and had therefore deliberately picked out a laboratory test to penalise his milk. He would be quite right. We are therefore practically forced to adopt one test or one method of testing throughout the year.

Is it practicable to adopt a double yardstick ? For example, could all producers be tested by a simple but accurate test for each of these two properties of keeping quality and bacterial content ? The obvious choices appear to be a dye-reduction test at a low temperature for keeping quality, and a simplified form of direct microscopic count test for bacterial content.

The latter has never found much favour in this country and there are grave objections to it. A simplified form of the test could be adopted if we are prepared to accept only three categories for classification of milk, as this would eliminate the necessity of counting all slides. It is possible to determine very quickly whether the direct microscopic count of the milk is, for example, below 600,000 or over 6,000,000 or safely in between these limits by a rapid glance at a few fields. On the basis of a ratio of 4 to 1 for the direct count against the plate count, this corresponds to limits of 150,000 and 1,500,000 for colony count. Further, there are various technical dodges that can be adopted for the purpose of a quick-grading direct count. For example, if the microscope has a factor of 600,000, these limits correspond to 1 and 10 organisms per field, so that it is only necessary to decide if the count is obviously less than 1 or over 10 for many samples. Others will safely fall about halfway. Only those appearing to average about 1 or about 10 per field need be counted. Another point is that a 3 in. × 1 in. slide is 19·4 or practically 20 cm.^{2}, so that 0·2 ml. milk spread over a whole slide will be the same as 0·01 ml. spread over 1 cm.^{2} This provides a less exacting technique and a smaller sampling error. A further device is the use of a $\frac{1}{8}$ in. dry objective and a high-power ocular.

If we refuse to admit the practicability of a double yardstick the problem becomes one of compromise—what order or priority and what weighting shall we give to the various aspects which constitute hygienic quality ? Is there a danger in confining our attention to only one aspect and ignoring the others ? Should we be content with tests such as the plate count or direct microscopic count which measure only bacterial numbers ? Or should we prefer the methylene blue test which measures keeping quality and bacterial numbers fairly accurately in warm weather but may fail to assess numbers in cold weather ? Or are we justified in using a composite test such as the resazurin test which is similar to the methylene blue test but gives an appreciable weighting to mastitis ?

The pros and cons of the common bacteriological tests are summarised in Table BG VII.

Milk Quality. What Does the Trade Want ? It is not surprising in view of the various difficulties which have been reviewed that the trade, *i.e.* the milk buyers and distributors, have never been able to agree on a clear-cut definition of what they require in the way of bacteriological quality in milk. There are, of course, two distinct problems here: (i) the problems of the country depot manager who has to receive milk from a number of farmers, cool the bulk, and send it to the large towns, usually in tanks; and (ii) the problems of the pasteurising and bottling manager who receives large bulks of brine-cooled milk which he has to pasteurise, bottle, and distribute to retailers. In the first case the manager has to be extremely careful to avoid accepting any milk which might turn the bulk milk sour before it reaches the pasteurising depot, and in the second case the manager has to satisfy himself that any milk which is put through his plant will yield bottled pasteurised milk of satisfactory keeping quality. It has never been agreed as to what standards should be demanded for (*a*) brine-cooled milk on reception at town depots and (*b*) keeping quality of bottled pasteurised milk from the time it reaches the consumer, but broadly speaking it may be said that if brine-cooled milk on reception at a bottling centre has a methylene blue reduction time of a half-hour or less (this is for practical purposes the same as reaching disc 0 in the resazurin test in half an hour or less), it is unsatisfactory. Correspondingly, if bottled pasteurised milk is delivered to the consumer, say, on Monday morning and is soured by first thing Tuesday morning, it is considered unsatisfactory. It may be suggested, therefore, that a reasonable standard from the point of view of the consumer is a keeping quality of twenty-four hours from the time of delivery to the consumer. For this purpose we may accept our third definition of keeping quality—the time required to reach the clot-on-boiling stage when held at atmospheric temperature. For the pasteurising and bottling manager a reasonable standard to suggest is a methylene blue reduction time of greater than an hour or alternatively resazurin not reduced to disc 0 in one hour. In other words, we may assume that if these were the minimum keeping qualities of milk received by the consumer and the bottling manager respectively there would be no complaints. When we come to relate these standards to that of the incoming raw milk of the country depot we are faced with a very difficult problem because there is no close relationship between the quality of farmers' milk as measured by any of the ordinary tests—sediment tests, titratable acidity test, plate count, direct microscopic count, methylene blue, or resazurin tests—and the keeping quality of the pasteurised article. It is well recognised by dairy bacteriologists and by processing managers that dirty milk, *i.e.* milk of high bacterial count or milk giving a short reduction time, *e.g.* half or quarter of an hour—may, on pasteurisation, give a milk of satisfactory keeping quality, and, conversely, milk of moderate bacterial count may give a pasteurised product of relatively high count and sometimes poor keeping quality. The answer to this apparent

TABLE BG VII

COMPARISON OF DIFFERENT BACTERIOLOGICAL TESTS FOR THE GRADING OF PRODUCERS

Plate count	*Coli*	*Microscopic count*	*Methylene blue*	*Resazurin (1 hour)*	*Clot on boiling*	*Sediment*
Advantages— Good psychological effect	Measures both keeping quality and hygienic aspects	Results available immediately Types of bacteria known at once Mastitis check	Simple inexpensive More accurate than 1 hour resazurin	Simple, inexpensive Quicker than M B Sufficiently accurate for grading	Actually measures keeping quality Best basis for quality payment	Best psychologically Very simple Immediate result
Disadvantages— Requires 2–3 days Expensive Not a good measure of keeping quality	Requires 2–3 days Fairly expensive	Expensive microscope necessary Fatiguing to worker Not accurate for clean milk	Longer than 1 hour resazurin	Less accurate than M B	Prolonged test but convenient if only grades required	Does not measure keeping quality or bacterial content

anomaly is that the effect of pasteurisation is a function of the *types* of bacteria rather than of numbers. Unfortunately there is no simple test which can predict the keeping quality of milk after pasteurisation, but the justification for having a rigorous platform examination and rejection standard at the creamery depends on three facts: (i) A small proportion of unsatisfactory milk may sour a large bulk of good milk in transit. (ii) There is a general feeling in the trade and amongst public health officials that there should be a pre-pasteurisation standard. In other words, although it may be possible to pasteurise a milk of a very high bacterial count, *e.g.* 50 million colonies per ml., and obtain a pasteurised product of satisfactory keeping quality, there are good hygienic reasons for an objection to such a pasteurised milk. (iii) Broadly speaking, when considering bulk milks, *e.g.* 3000 gallons, in which the milk of some two or three hundred producers may be mixed, the bacterial content and keeping quality of the pasteurised product is related to the bacterial quality of the raw supply.[8]

What standard should be applied on the platform ? If we accept that bulk milk after transit in tankers should arrive with a methylene blue reduction time of greater than an hour, it is obvious that we should not accept milk of much below this quality on the creamery platform. At the present time, milk which reduces resazurin to disc ½ or 0 (which means the same thing as a methylene blue reduction time) in ten minutes should be automatically rejected, and creameries are entitled to reject milk if it gives a disc reading of less than 4 on the ten-minute test. A disc reading of 3½ in the ten-minute test corresponds roughly to a methylene blue reduction time of half an hour. It is apparent, therefore, that a rejection standard of disc ½ or 0 is lenient and that there is considerable justification for a universal standard of disc 3½ or less for platform rejection.

If we require that all milk coming into the creamery should not reduce methylene blue in one hour, we are faced with the problem either of keeping the churns back for one hour while the test is made or if we used the resazurin test this could be achieved in half an hour by the use of a standard for rejection, say, at disc below 4, or of finding a quick test which would pick out milk which fails the standard. At present no such test is known. The first requirement, then, of any attempt to raise the standard of examination of incoming milks is to find a simple quick test which can pick out milks which would reduce methylene blue in one hour or less.

Category Values. Considering now the valuable information which has been afforded to the dairy industry by the National Milk Testing [and Advisory] Scheme over some six years, it has been found that a large proportion, *viz.* some 80 per cent., of producers are able to supply milk of category A quality on most occasions in cold and moderate weather. Since the routine test gives us far more valuable information about the quality of producers' supply than the rejection test, because it is applied to all producers and is a more accurate test, we should pay more attention to the information given by the analysis of categories for producers than to results of any other test. Category A in this test is a fairly easy standard, being somewhat more lenient than the accredited standard. It is suggested, therefore, that a reasonable requirement for all producers would be that their milk should come in category A on at least 75 per cent. of tests and that they should have no category C results. Category C indicates a really bad quality in the milk, and the proportion of producers giving category C results varies from about 2 per cent. in cold weather to about 30 per cent. in very hot weather. The mean value is somewhere about 10 per cent. It is interesting to note that creamery managers estimate that from 5 to 10 per cent. of their producers are really unsatisfactory and are the cause of all the trouble. There is considerable justification, therefore, for assuming that category C farmers are those who are giving real trouble, and that it is reasonable to expect that no farmer should ever send any milk of category C quality unless there are some exceptional circumstances for it.

[8] Anderson and Meanwell (1949), *JRSI*, **69**, 24.

It is suggested, therefore, that if the milk producers of the country could be raised to this standard, *i.e.* at least 75 per cent. category A and no category C, the occasions of trouble due to souring of tanker milk and the issue of unsatisfactory pasteurised milk to consumers would virtually disappear, provided refrigeration at the depot, transport, and pasteurisation and bottling at the depot were efficient.

General Conclusions. We may summarise the subject by the following statements:

(1) There is no one definable property concerned with the bacteriological quality of milk which is adequate to cover the whole range of producer, distributor, and consumer requirements.

(2) If we adopt a single property, *e.g.* a plate count or keeping-quality test, we must recognise that this is quite empirical and arbitrary and leaves untouched other very important aspects of the problem.

(3) The requirements for the quality of milk in the dairy industry are very variable. It is impossible to cater for all these by any one test. If we propose to base the bacteriological control of milk on one test, we should consider the fact that there is an increasing tendency for milk to be delivered to a country depot at anything up to eighteen hours old, there cooled to about 38° F., sent in bulk some distance, pasteurised in a town, again cooled to a low temperature, and distributed to the consumer. The closer we can get our test to take into consideration this chain of treatment the greater will be the commercial use of the control scheme.

(4) It is suggested that the most important factors in the bacteriological control of milk are (*a*) numbers and (*b*) keeping quality. If we can evolve a practical scheme which covers both these attributes, *e.g.* by adopting simple grading tests for each factor separately, we shall have covered the problem more satisfactorily than by using any one single test, no matter how accurate it may be as a measure of any one of these factors.

If we consider that the use of two tests is out of the question we should then search for the test which gives us the maximum amount of information about the hygienic quality of milk in a broad sense, due consideration being given to the weighting attached to the various components of which hygienic quality is composed.

(5) Under the present testing schemes the following are suggested as reasonable standards: (*a*) On the creamery platform—time to reach disc ½ or 0 or methylene blue reduction time greater than one hour. (*b*) At the pasteurisation depot—as for (*a*). (*c*) In the household—a commercial keeping quality of at least twenty-four hours.

If these standards could be attained, the milk supply of the country could be regarded as satisfactory from the keeping quality point of view. *See* Clean milk production; Legal aspects; Management of creameries;—of pasteurising depots; Methylene blue test; Microscopic count; National milk testing scheme; Plate count; Quality payment; Resazurin test.

Refs.: Chalmers; Wilson *et al.*; *Milk Testing:* Thomas *et al.* (1951), *SAB*, **14**, 191 (temp. compensation); Garvie and Rowlands (1952), *JDR*, **19**, 133, 263; Davis (1950), *JRSI*, **70**, 227; Rowlands and Hosking (1951), *JDR*, **18**, 268; Rowlands *et al.* (1950), *JDR*, **17**, 159; Eddison *et al.* (1951), *JDR*, **18**, 43; Rowlands and Hosking (1951), *JDR*, **18**, 166 (K.Q. of raw milk); Clegg (1949), *SAB*, No. 2, 69, 79; Clegg *et al.* 87 (temp. compensation); Feagan *et al.* (1951), *DI*, **16**, 151 (temp. compensation); Rowlands (1947), *Brit. Med. Bull.*, **5**, 196; McClemont, *ibid.*, 201; Anderson and Wilson (1946), *JDR*, **14**, 21 (resazurin and *MB* compared); Barkworth *et al.* (1941), *JDR*, **12**, 265 (plate count and methylene blue test).

BACTERIOLOGICAL STANDARDS FOR DAIRY PRODUCTS. *See* Bacteriological grading; Quality payment; Testing of milk supplies.

Refs.: Davis (1952), *D*, **69**, 347, 406; Davis and Ashton (1951), *JSDT*, **4**, 78.

BACTERIOLOGY, DAIRY. The advances in this subject are described in the following reviews:

Mattick, Hiscox and Christian (1933), *JDR*, **4**, 285; Mattick, Hiscox and Davis (1935), *JDR*, **6**, 422; (1937), *JDR*, **8**, 369; (1939), *JDR*, **10**, 515; (1941), *JDR*, **12**, 350; Hiscox and Rowlands (1947), *JDR*, **15**, 170; Hiscox and Hirsch (1951), *JDR*, **18**, 207; Hiscox and Briggs (1953), *JDR*, **20**, 381.

Text-books. Chalmers; Demeter; Hammer; Orla Jensen; Rogers; Demeter, Section on dairy bacteriology in Lohnis' *Handbuch der landwirtschaftlichen Bakteriologie* (in German, comprehensive); Dorner, Demont and Chavannes (1945), *Microbiologie laitière*, Lausanne; Knudsen (1944), *Lectures on Dairy Chemistry and Dairy Bacteriology* (in Danish), Copenhagen; Tanner (1944), *The Microbiology of Foods*, Champaign, Ill.; Prescott and Dunn (1940), *Industrial Microbiology*, New York; Koroleff (1932), *Principles of Microbiology in the Dairy Industry* (in Russian), Moscow.

BACTERIOPHAGE. *See* Starters.

BACTERIOSTATIC. This term is analogous to bactericidal (p. 62) but is limited to substances or conditions preventing growth only, not killing. Many of these substances or conditions will exert a bacteriostatic effect in very small concentrations and a bactericidal effect in higher concentrations. Cold is the classical example of a bacteriostatic condition in the dairy industry (*see* Refrigeration and Cooling of milk) while others are dryness (*see* Milk powder), smallness of water globules (*see* Butter) and high salt concentrations (*see* Cheese). *See* Disinfectants; Stability.

Refs.: McCulloch; Wilson and Miles.

BACTERIUM. (i) In a general sense any micro-organism, excluding yeasts and moulds. (ii) In the strict sense of nomenclature a non-spore-forming rod-shaped organism. (iii) Used as the name of a *genus* the term has different senses, the English being broader than the American. *See* Classification.

Refs.: Bergey; Wilson and Miles.

" BAG ". A colloquial term for udder.

BAIL OR OPEN-AIR SYSTEM OF MILKING. A method of milk production in which the cows are kept in the open and milked and fed in a mobile house or bail, usually constructed of wood and metal. By this method the fertilising value of the dung and urine is retained on the fields, the expense of a permanent cowhouse is avoided, and the cows maintained in better health and the pastures improved. It is particularly suited to light, high land. It is claimed that costs of production are less.

Increase in ley farming in recent years has seen a corresponding increase in " bailing ". It improves soil fertility, and because the complete outfit—milking shed, dairy, and machine-room—is taken to the cows in distant or off-lying pastures, they retain their healthy outdoor condition. In some districts, particularly Wiltshire, bailing is carried on all the year round. A modern milking bail, fitted with a three-point Auto-Recorder machine, is capable of dealing with six cows at a time. The portable bail is useful as a means of increasing milk production where existing cowsheds are too small for the number of cows the land will carry or of maintaining it where sheds are under repair. An improvement in the general health of the herd is observable when it is milked under these conditions. As the bail is moved to a fresh site each day, it can bring into cultivation land previously considered fit only for sparse hill grazing because each site is manured and trodden directly. Bailing can provide the highest grade milk under conditions as hygienic as other modern methods, because the milking machine is identical with those used in fixed sheds.

The direct return of all dung and urine to the land is an important feature in the bail system. Modern sanitation and methods of sewage disposal have undoubtedly reduced the incidence of infectious disease, but have also resulted in the steady loss of manurial values. Of these calcium is not serious, as lime is plentiful, and nitrogen can be replaced by the nitrogen-fixing bacteria. Humus and phosphate are important, however, and the potash question is one of marked significance. As an example of the loss of nitrogen, it may be pointed out that the urine of a family of four excreted in twenty-four hours contains sufficient nitrogen to form nearly half a hundredweight of potatoes. *See* Management of dairy cattle; Milking machines.

Refs.: Hosier and Hosier (1951), *Hosier's Farming System;* Dixey and Messer (1933), *Open-air Dairying; A Survey of Farms Using Milking Bails in* 1932, Oxford.

BAKER'S CHEESE. A product formerly made with skim milk powder, starter and rennet.

BALANCE TANK. A tank into which a liquid such as milk can be pumped and drawn off at will, *e.g.* for bottling or can filling.

BALANCED RATION. For correct nutrition, animals require not only an adequate amount of energy foods to supply calories but also enough protein to provide for growth and normal waste, vitamins, and minerals. In devising a ration for a dairy cow, therefore, particular attention must be paid to the proportion of protein, etc., in the food. *See* Feeding.

BANG'S BACILLUS. A name sometimes given to the organism of contagious abortion after the Danish bacteriologist Bang. *See* Abortion; Brucella; Classification; Undulant fever.

Refs.: Miller; Wilson and Miles.

BASICITY. The number of hydrogen atoms in the molecule of an acid, which can be replaced by a base. *See* Acidity.

BAUDOUIN'S TEST. This is a test for adulteration of butter by sesame oil. The fat is melted and shaken with a solution of cane sugar in hydrochloric acid. If the acid layer goes pink it indicates the presence of the oil.

For Villavecchia and Fabris' modification *see JSCI* (1894), **13**, 69 and *IEC* (A) (1940), **12**, 380.

" BEESTINGS ", " BEASTLINGS ". A colloquial term for Colostrum (p. 272).

BELGIUM.

Ref.: Devriendt (1949), *IDC*, **4**, 504.

BELLALAY. *See* Cheese, p. 184.

BEL PAESE. *See* Cheese, p. 184.

BENZOIC ACID. This preservative is used for brine rennet solutions, being present to the extent of about 1 per cent. (*see* Rennet). For the method of detection in milk *see* Revis (1912) *A*, **37**, 346; Hinks (1913), *A*, **38**, 555; Illing (1932), *A*, **57**, 224.

BETABACTERIUM. The name given by Orla-Jensen to the genus of heterofermentative lactobacilli. It is identical with Lactobacillus III. *See* Lactic acid bacteria.

BETACOCCUS. The name given by Orla Jensen to the *genus* of heterofermentative streptococci. It is identical with *Leuconostoc* and Streptococcus III. *See* Lactic acid bacteria.

BICHROMATE. Potassium bichromate ($K_2Cr_2O_7$) can be used to preserve milk for fat, but not for solids-not-fat analysis. *See* Brine; Corrosion.

BILE SALT. This media constituent is used in the bile salt (MacConkey) broth for the presumptive test for coli. It is also called sodium tauroglycocholate, which is the chief constituent. *See* Coliforms.

BIOCHEMICAL REACTIONS. There are three main groups of tests for identifying bacteria—cell shape, spores, flagella, etc.; serological reactions; and biochemical reactions. The most important of this last group are sugar fermentations, gelatine liquefaction, nitrate reduction, catalase, and Voges-Proskauer reactions. *See* Classification ; Coliforms ; Lactic acid bacteria.

Refs.: Bergey; Buchanan and Fulmer; Cunningham; Wilson and Miles; Clarke and Cowan (1952), *JGM*, **6**, 187; Davis (1939), *ZB II*, **101**, 97 (metabolic tests).

BIOLOGICAL OXYGEN DEMAND. Micro-organisms in milk, water, sewage, etc., consume oxygen by respiration, and the figure for this (B.O.D.) gives a measure of microbial activity. Its significance in milk is chiefly in relation to oxidative faults such as oiliness in milk (p. 475). Bacteria can prevent this fault by consuming the dissolved oxygen in the milk. *See* Effluent.

BIORISATION. A method of heat-treatment in which the milk is sprayed or atomised in the pasteurising vessel. It is now obsolete.

BIOS. The early name for a growth factor for yeast. *See* Vitamins.

BIROTATION RATIO (also called muta- or multi-rotation). Certain sugars when dissolved in water gradually change in their optical rotation. Thus lactose exists in three forms. The common form is the α-monohydrate (specific rotation $+89{\cdot}4^\circ$) but after standing for twenty-four hours an equilibrium mixture of the α and β forms is reached with a specific rotation of $+55{\cdot}5^\circ$. The presence of other sugars can be detected by changes in the birotation ratio.

" BISHOP ". A breakdown, especially in canning.

BISON MILK. *See* Mammals.

BITCH MILK. *See* Mammals.

BITTERNESS. A characteristic fault in dairy products, especially in cheese and milk. It is supposed to be associated with " peptone ", but may be related to the presence of tributyrin, as this is extremely bitter. It is usually caused by certain organisms growing at low temperatures, particularly those attacking protein and fat. *See* Cheese ; Flavours.

BLACK SPOT IN BUTTER. A fault which may be caused by bacteria (p. 968) or moulds. *See* Butter ; Stability, microbiological.

Refs.: Davis (1951), *SAB*, **14**, 216; Hiscox (1936), *JDR*, **7**, 238.

BLEACHING POWDER. The commercial name for calcium hypochlorite which usually contains about 37 per cent. available chlorine. It has been largely replaced in the dairy industry by concentrated solutions of sodium hypochlorite of known strength, usually about 10 per cent. available chlorine. *See* Chlorine.

BLENDING. The mixture of two or more kinds of a product to attain a standardised product, particularly in relation to butter (moisture content as near 16 per cent. as possible) and milk (fat content to give the required fat content for a milk product such as milk powder). The term is also used colloquially to describe the mixing of poor quality with better quality milk.

BLEU. *See* Cheese, p. 184.

BLICHFELDT'S METHOD FOR BUTTERFAT. A method for examining butterfat, involving the determination of the soluble volatile acids and soluble silver salts. *See* Blichfeldt, *JSCI* (1919), **38**, 150 T.

BLOAT IN CATTLE. *See* Diseases of dairy cattle.

" BLOATS " (" SWELL HEADS "). Blown cans of evaporated milk and canned cream due to gas production by bacteria. *See* Condensed and evaporated milk ; Cream, canned ; Stability.

Refs.: Baumgartner; Hunziker; Tanner; Nichols (1939), *JDR*, **10**, 231.

BLOCKMILK. A concentrated solid form of milk containing 40 per cent. sugar. It is usually coated with cacao butter.

BLOOD. Milk is formed from blood by the milk-secreting cells of the mammary glands. The compositions of blood and milk are illustrated below (Table Bl 1). *See* Milk secretion.

TABLE BI I

Constituent %		Blood		Milk	
		(human)	*(bovine)*	*(human)*	*(bovine)*
Total solids . .		19-23	19	12–13	12–14
Total proteins . .		6·5–8·2 (serum)	7·2	1·2–2·2	3·4
Albumin . . .		4·6–6·7 (serum)		0·4	0·4
Globulin . . .		1·2–2·3 (serum)		?	0·05
Fibrinogen . .		0·3–0·6	0·7	0	0
Haemoglobin . .		15·6	12·0	0	0
Total nitrogen . .		3·0–3·7		0·2	0·5
Casein . . .		0		0·8	3·0
Iron . .	mg.	52		0·1	0·1
Copper	,,	0·05–0·25		0·05	0·01
Calcium	,,	9–11·5	8	36	120
Magnesium	,,	1–3	3		9
Sodium (Na_2O)	,,	330	430		77
Potassium (K_2O)	,,	16–22	26		149
Chloride	,,	450–500	370		80
Phosphorus (inorganic)	,,	3–4	3	18	95
Ash	,,		20–40	200–250	750
Non-protein N	,,	25–35			
Lactose	,,			6·5–7	4·7–4·8
Glucose	,,	70–100	40–60	?	?
Fatty acids	,,	290–420		trace	trace
Cholesterol	,,	150–190	50–230		
Fat	,,			3–4	3·3–4·3
Citric acid	,,		0		240

BLOOD AGAR. *See* Media.

BLOOD IN MILK. Acute cases of mastitis and mechanical injury to the teat, etc., can result in the presence of blood in milk. Such milk is usually rejected on the platform. *See* Abnormal milk ; Mastitis.

" BLOOM ". The cloudy appearance of the surface of bottles due to deposition of various substances or to certain chemical changes on the surface of the glass. *See* Bottles ; Bottle washing.

" BLOWING " OF CONDENSED MILK. The bulging or bursting of tins of condensed milk usually due to the production of carbon dioxide by fermentation of the sugar by micro-organisms, usually yeasts. *See* Condensed milk; Stability.

BLUE-VEINED CHEESE. A term applied to Stilton, Wensleydale, Roquefort, and Gorgonzola cheese, in which the blue-green mould, *Penicillium roqueforti*, grows in cracks and is an important ripening agent. *See* Cheese.

BLUE VINNEY (or **DORSET BLUE**). *See* Cheese, p. 190.

BOARD OF TRADE UNIT. Of electrical current, 1000 watt-hours or 1 kilowatt-hour.

BODY. In grading butter and cheese this term denotes firmness, a complex quality which considers chiefly viscosity but also elasticity. *See* Rheology.

BODY CELLS. Milk as it leaves the udder contains a highly variable number of cells derived from the glands, blood, and other tissues. The number is normally less than 100,000 per ml. when the udder is healthy, but may rise to one or more millions when it is diseased. In clinical cases of mastitis the number may amount to 10 or 20 millions.

These cells have a reducing power of considerable capacity, but low potential, and hence they affect resazurin appreciably, but methylene blue only slightly.

On ageing the milk, the cells gradually disintegrate and the reducing power diminishes considerably. *See* Abnormal milk; Mastitis; Milk secretion; Resazurin tests.

Refs.: Miller; Thomas (1941), *DI*, **6**, 41 and 102; Thomas *et al.* (1941), *DI*, **6**, 269, 295 and 323.

BOG BUTTER. In Ireland butter is buried in the peat bogs for storage purposes. This butter has on occasion been recovered after many years ageing and chemical analyses have shown that the fat has been completely hydrolysed to fatty acids, the soluble acids have almost disappeared and hydroxy derivatives of the higher acids have formed presumably by oxidation.

Refs.: Radcliffe and Maddocks (1907), *JSCI*, **26**, 3; Hart, *ibid.*; Arup (1932) *A*, **57**, 300.

BOILERS. *See* Steam raising.

BOILER WATER, TESTS ON. *See* Water, boiler, control of.

Ref.: Dickinson (1950), *Chemical Analysis of Waters, Boiler and Feed Waters, Sewage and Effluent*, London; Matthews (1951), *Boiler Feed Treatment*, London; Jenkyns (1945), *Boiler User's Guide*, London.

BOILING. The vigorous evaporation, or conversion into vapour, of a liquid. Boiling may be caused by raising the temperature or lowering the pressure.

BOILING POINTS. Water, 100° C., 212° F.; Alcohol, 78° C.; Ether, 35° C.; Mercury, 357° C.; Ammonia, − 33° C.

BOILING TEST. It is universally accepted that if milk will not boil without clotting it is unfit for use. *See* Clot-on-boiling; Bacteriological grading of milk; Quality payment.

BÖMER'S METHOD. A method for the examination of butterfat depending on the difference between the melting points of the glycerides less soluble in ether and their fatty acids (1914) *A*, **39**, 84 and 171.

BONDON. *See* Cheese, p. 184.

BORATES, BORAX AND BORIC ACID. These chemicals, boric or boracic acid and borax or sodium tetraborate, were formerly used for preserving dairy products, especially cream which could contain 0·5 per cent. Its use has been illegal since 1926 but brine rennet commonly contains about 1 per cent. boric acid. Its presence in milk is readily detected by placing about 0·5 ml. of the milk on a white tile and adding 1 drop turmeric solution and 2 drops $\frac{N}{5}$ hydrochloric acid. On drying by gentle heat a pink colour appears which changes to olive green by adding bicarbonate. This test is very sensitive and will detect as little as 0·005 per cent. boric acid.

Refs.: Richmond; Owen (1944), *JDR*, **13**, 243 (excretion of borate by cows).

BOTTLES. Modern bottle glass contains about 74 per cent. silicon dioxide, the remaining 26 per cent. comprising calcium and magnesium oxides and sodium oxide, which are used as fluxes to enable the silica to be melted at temperatures which permit the furnace refractories to last a reasonable time. The object of

TABLE Bo I

COMPOSITION RANGES OF TYPICAL BOTTLE GLASSES

Colourless	%	*Dark green or amber*	%
SiO_2	73–74	SiO_2	65–70
Al_2O_3	0·5–2	Al_2O_3	3–5
CaO	6–10	CaO	8–10
MgO	0–3	Na_2O	15–17
Na_2O	15–16	Fe_2O_3	1–2
Fe_2O_3, SO_4, etc.	0·5	MnO	0–2

the glassmaker is to retain the chemically inert, non-absorbent properties of silica in a material which can be fashioned into containers on an automatic mass-production scale.

The raw materials used are sand (SiO_2), limestone ($CaCO_3$), soda ash (Na_2CO_3), and saltcake (Na_2SO_4), with traces of colouring agents as required. All the materials can be obtained in good quantity in Great Britain, with the exception of some colouring agents such as selenium (used to produce pink colours), or cobalt oxide (blue). The familiar amber of beer-bottles is obtained by adding to the raw materials sulphur and carbon, or other reducing agents, thereby introducing sulphides or polysulphides in solution in the melt. Green colours are obtained by the addition of iron or chromium salts to the batch; in fact, the chief difficulty in making colourless glass is to exclude small traces of iron or chromium, so powerful is their colouring action. As little as 0·04 per cent. Fe_2O_3 produces a distinct green tinge in glass, and 0·003 per cent. Cr_2O_3 is also easily observed. In making colourless glass, the green tinge due to small amounts of Fe_2O_3 is usually neutralised by adding a trace of selenium metal to the batch, the pink colour thereby produced being complementary to the green due to the iron.

(1) **Furnaces for Melting Bottle Glass.** The raw materials are melted together in large tank furnaces, so called because they consist of a rectangular tank of refractory blocks, usually about 20 ft. wide, 30 ft. to 40 ft. long, and 3 ft. to 4 ft. deep.[1] The furnaces are recuperative, or more generally regenerative, and are heated by producer gas, coke-oven gas, or oil, with the flames passing across the tank above the molten glass, while the raw materials are fed continuously on the surface at one end. The temperatures above the glass vary from 1420° C. to 1530° C., the latter being used to obtain high melting rates. As much as one ton of glass per day is produced for each 5 sq. ft. of furnace area at the higher temperatures, so that a furnace of average size can produce 120 tons of glass per day when operated at 1530° C. A more usual output at present would be about 80 tons per day, the optimum output depending on the ability of the refractories to resist glass corrosion at the temperature employed, and on the type of bottle making machines and their disposition round the furnace.

From the melting chamber the glass is drawn through a submerged refractory throat into a second chamber, where it is cooled to the operating temperature necessary for the machines. The use of a submerged throat enables the scum and partly melted " batch " to be kept on the surface in the melting end, while the melted glass passes to the machines.

In recent years experiments have been made to melt glass electrically.[2] In this method the electrical resistance of the glass itself is used to generate heat, the electric current being led into the molten glass by carbon or air-cooled metal electrodes. The system is used commercially in countries where coal is scarce. and abundant cheap electric power is available, but the melting cost is too high as yet in countries where a supply of coal or oil is found. The success of the method depends on the rapid increase in electrical conductivity of glass above the softening temperature, despite the fact that it is a very good insulator at room temperature.

(2) **Annealing.** When a bottle has been finished by a machine it has an average temperature of about 650° C., some parts being at lower and others at higher temperatures. During the subsequent cooling to room temperature the glass changes from a plastic material to a hard solid, the process being almost complete in bottle glass at about 450° C. It is essential that the material shall not set hard while temperature gradients exist in it, for during the plastic stage the glass can yield to the stresses set up by thermal gradients and thereby reach a state in which no internal stresses occur; when the glass is cooled, however, it cannot yield to

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[1] *A Textbook of Glass Technology*, F. W. Hodkin and Cousen (1925), London.

[2] Meigh (1931), *J.S.G.T.*, xv, 321.

stresses, so that when the thermal gradients are removed at room temperature permanent internal stresses are set up.

The object of the annealing process is, first to bring the bottle to a uniform temperature throughout, and secondly to cool it very slowly until the glass is " set " at about 450° C. By cooling slowly it is ensured that only very small temperature gradients exist in the glass during the setting process. Below 450° C. the glass may be cooled as rapidly as is possible without cracking it.

Internal stresses may be detected in glass by inspection in polarised light.[1] Glass which is strained behaves like a bi-refractive crystal, so that when viewed between crossed Nicol prisms it shows light against the dark background. Various instruments based on this property are used to detect internal stresses, most of them having a quarter-wave plate in the eye-piece, which gives a coloured background, so that rotation of the plane of polarisation by the stressed glass produces changes of colour. The results of examining glass in such instruments require skilled interpretation as very small stresses cause large colour changes, but further increases in stress produce much smaller colour changes. It is also necessary to distinguish between compressive and tensile stresses in the glass, because a uniform compressive stress can be beneficial. Since glass fails in tension, any applied stress must first overcome the compression, thereby enabling the glass to resist greater stresses.

(3) **Bottle-making Machinery.** Bottles are made almost entirely by fully automatic machinery, the exceptions being when small orders are required or when unusual shapes are made which are not capable of automatic moulding. The essential operations are the same whether bottles are made by hand or by machine : a " gather ", or lump of hot plastic glass, is collected from a molten pool ; a preliminary operation of blowing and shaping is used to prepare the mass into a rough shape ready to be placed in a mould ; and finally, the rough shape, or " parison " as it is called, is blown up into the mould thereby taking up the shape of the finished bottle. In automatic manufacture the " gather " is collected from the pool either by sucking the molten glass into a metal mould by means of vacuum, or by extruding the molten glass through an orifice and cutting off the desired amount with sharp, water-cooled, metal shears. In either case the machine next forms the mass into a parison, transfers this to the final mould and there blows the finished bottle.[2] Automatic manufacturing methods employing machines with up to fifteen moulds, each of which makes two bottles at a time, can produce between 100 and 200 small bottles in one minute, and one remarkable machine developed by the Corning Glass Works in U.S.A. can make over 600 electric lamp bulbs per minute. Naturally, speeds of these orders can be used only when very large quantities are required, because the setting up of the machine and " warming up " periods are lengthy. The more usual production speeds are in the range from 20 to 60 per minute with a minimum number of moulds on a machine to facilitate starting up and reduce overhead costs.

(4) **The Chemical Durability of Glass.** The silicate glasses are considered to be made up of a random arrangement of 0—Si bonds with a constitution similar to that of a liquid. The sodium, calcium, and other atoms are interspersed throughout the silica matrix, and evidence obtained from electrolysis of glass indicates that the sodium, at least, is in the ionic state.

The resistance of glass to chemical attack is due to the inert character of the silica, but the sodium at the extreme surface may be leached out by water or acid. The amount removed is exceedingly small, and after the first attack very little more alkali can be removed until the silica matrix itself is broken down, which can be only effected by prolonged high temperature treatment. Professor W. E. S.

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[1] Preston (1930), *J. Am. Cer. Soc.*, **13**, 595 ; Murgatroyd (1932), *J.S.G.T.*, **xvi**, 6.

[2] *A Textbook of Glass Technology*, Chap. xxxii ; *Glass, The Miracle Maker*, Phillips (Pitman).

Turner and his colleagues at Sheffield[1] have made many studies of the durability of glass, and these are recorded in the *Journal of the Society of Glass Technology*. It is of interest here to quote the work on the effect of filling bottles with distilled water and subjecting them to steam treatment at 100° C. for five hours. At the end of the test the amount of Na_2O removed from the glass was estimated by titration, and the results of successive tests are given below as milligrams of Na_2O removed per sq. decimetre of internal glass surface in the bottle :

1st Test	*2nd Test*	*3rd Test*	*4th Test*	
2·89	1·08	0·91	0·81	mg . Na_2O/sq. dm.

Since alkali is practically the only material removed from glass by chemical attack (except, of course, in the case of hydrofluoric acid, which attacks the silica) it is necessary to use a relatively low alkali glass, and to remove the surface alkali by washing, when a container is required for delicate chemicals which are extremely susceptible to traces of alkali. For this purpose the surface alkali is often removed by spraying sulphurous gases on the glass while it is being subjected to the annealing process. The alkali sulphate so formed is readily washed off in cold water leaving a practically alkali-free surface. It is, however, only in the case of certain alkaloids in very small containers for which the ratio of surface area of glass to volume is large, that any account need be taken of the possibility of soda solution.

(5) **Physical Properties of Bottle Glass.** The commoner physical properties of bottle glass are given in Table Bo II which refers to glasses of composition similar to those quoted in Table Bo I.

TABLE Bo II

PHYSICAL PROPERTIES OF TYPICAL BOTTLE GLASS[2]

Specific gravity	2·47 to 2·49 gms./ml.
Specific heat	0·28 calories/gm./° C.
Thermal conductivity . . .	2×10^{-3} cal/.cm.^{2}/sec.$^{-1}$ (gradient 1° C. per cm.).
Thermal expansion . . .	8 to 9 $\times 10^{-6}$ cms./cm./° C.
Tensile strength	5000 to 7000 lbs./in.^{2}.
Softening temperature . . .	About 500° C.

(6) **Care and Treatment of Bottles.** The glass container has the advantages of being cheap, chemically inert, and non-absorbent, and can be made in an almost infinite variety of shapes to dimensional specifications which do not change after manufacture. This inability to yield permanently under stress is, however, the cause of the chief drawback to glass, namely, its fragility. Despite its relatively high tensile strength of 5000 to 7000 lb. in.^{2}, the fact that glass is not ductile like metals causes it to receive very high stresses in impact or when other point-loads are applied. Hence all handling equipment should be designed so that where bottles receive impact in washing, filling, capping, etc., the impact is administered by a surface which can yield and thereby spread the load. Materials such as wood, plastics, hard or soft rubber, or soft metals, where metals are needed, are best at such points. In modern dairies, where the staffs co-operate in handling bottles carefully, milk bottles are capable of averaging seventy journeys or more before being broken ; and forty journeys (each journey including washing, filling, capping, loading, and carriage to customer and return) is quite common.

A frequent cause of breakage is the application of excessive thermal shock to bottles. Glass fails in tension, and in thermal shock the maximum tensions are caused when the *outside* of a hot bottle is chilled. Another type of thermal shock causing dangerous stresses is caused by heating a bottle rapidly on the

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[1] A résumé of this work is given by Cousen (1936), *J.S.G.T.*, **xx**, 418.

[2] For a fuller account of the properties of glass *see The Properties of Glass*, Morey, 1938 (Reinhold Publishing Corporation).

inside (as by filling a cold bottle with hot liquid).[1] The sound rule to remember is : cool a hot bottle by applying cold liquid to the inside only, and heat a cold bottle by applying the heat at first to the outside only. Temperature differentials of 30° C. should not be exceeded in cooling processes, or 50° C. in glass heating processes, these representing the difference in temperature between the glass and the chilling or heating medium. If care is taken to ensure that only the inside is cooled, or only the outside of the bottle heated, these temperature differentials may safely be doubled.

The normal design of bottle may be regarded as a cylinder with one end closed, and the maximum stress under thermal shock in a closed cylinder occurs in the cylinder wall near the closed end.[2] Hence it is advisable to ensure that no bruising of a glass bottle occurs in the cylinder wall for a distance of about ½ in. up from the base. Bruises lower the resistance to thermal shock and are therefore particularly liable to cause breakage where maximum stresses come into play. Hence all handling processes should be designed to avoid bruising the wall near the base of a bottle.

If care is taken in the heating and cooling processes, glass may be heated to 400° C., if necessary, in order to produce a sterile surface, and no distortion will occur at this temperature. *See* Costings, p. 309.

Abbreviations : *Journal of the Society of Glass Technology—J.S.G.T.*
Journal of the American Ceramic Society—J.Am.Cer.Soc.

Refs.: Moore (1951), *JSDT*, **4**, 160; Seddon (1951), *JSDT*, **4**, 166; B.S. 1925 (1953) (capacity).

BOTTLE CAPACITY. B.S. 1925 (1953) gives the tolerances for ½ and 1 pint and 1 quart milk bottles (ordinary) and also a method for measuring the capacity of a number of bottles.

BOTTLE CAPPING. *See* Bottle filling.

BOTTLE CONTAMINATION, EFFECT ON KEEPING QUALITY. The smaller the container the greater the effect of contamination (per unit surface area) on keeping quality. For this reason dirty bottles have a relatively large effect on the keeping quality of pasteurised milk. *See* Bottle washing ; Dirty churns ; Pasteurisation ; Quality payment ; Surface to volume ratio.

Ref.: Phillips (1946), *SAB*, p. 94.

BOTTLE FILLING AND BOTTLE CAPPING. The Container. The approaches to the subject of filling milk bottles or other retail containers in which the householder's daily supply is delivered are so many and varied that a choice is difficult if the whole field is to be adequately covered in the limited space here available.

A useful purpose may, however, be served by considering at the outset the types of container at present in use for the retail distribution of milk. Of these we may dismiss, after mentioning it, the tinned steel can with its familiar wire handle. It has now been entirely replaced by the more convenient glass milk bottle and by the waxed paper carton, both of which containers are admirable for their purpose. Before we consider the glass bottle now in such general use, a word or two should be allowed for the carton in explanation of the decline in its use after such a promising start during the years immediately preceding the late war.

The waxed paper carton was then available for holding milk in capacities of ½ and 1 pint. Mostly these were pre-formed and supplied to the dairyman ready for filling. For larger dairies, however, the question of handling, unwrapping from sealed packages and feeding into the fillers such large numbers of cartons as were required, called for a more economical type, one made on the dairy premises by special machinery. This involved only the supply to the dairy of rolls of paper. The machine automatically made the complete carton to a uniform size,

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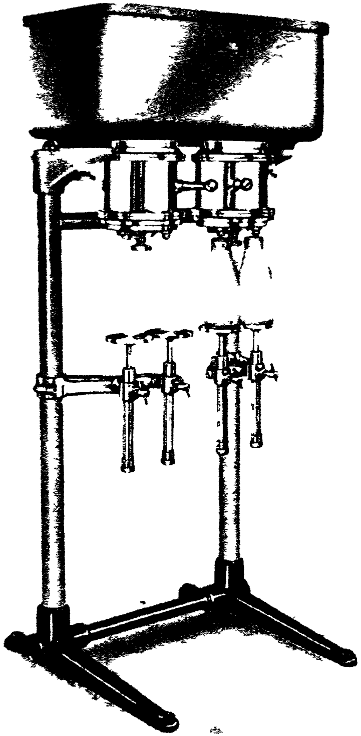
[1] Murgatroyd (1932), *J.S.G.T.*, **xvi**, 7, also (1936), *J.S.G.T.*, **xx**, 511.

[2] Murgatroyd (1943), *J.S.G.T.*, **xxvii**, 77.



[*By courtesy of G Hopkins & Sons Ltd*

FIG BF 1 —"*Multifiller*" *Quantity Filling Machine*

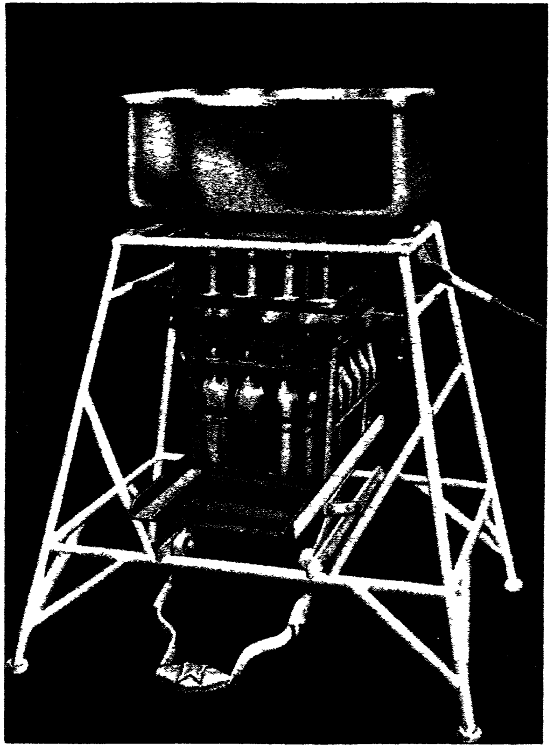


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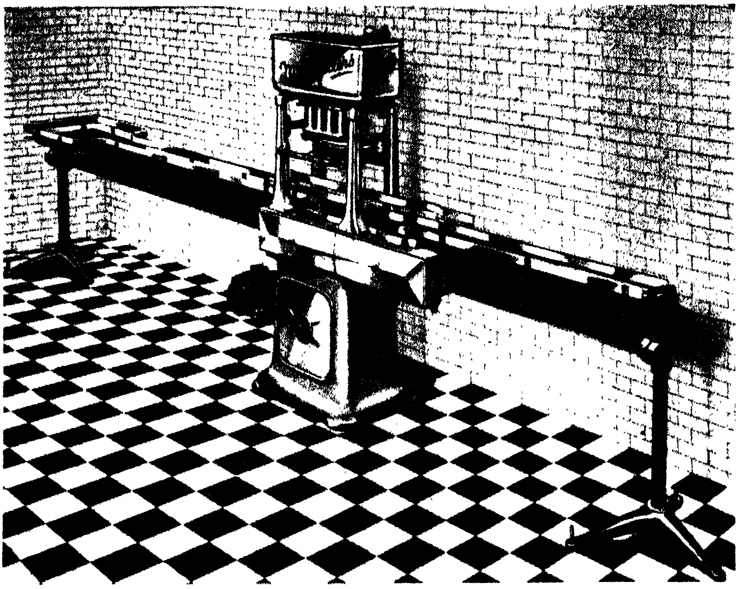
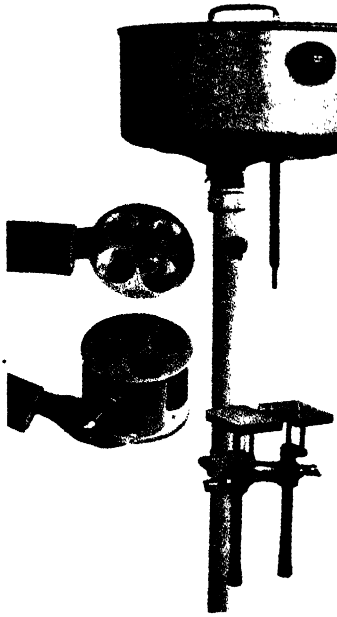
FIG BF 2 —"*Multifiller*" *Quantity Filling Machine.*



[*By courtesy of G. Hopkins & Sons Ltd.*

FIG. BF 3.—" *Multifiller* " *Quantity Filling Machine.*

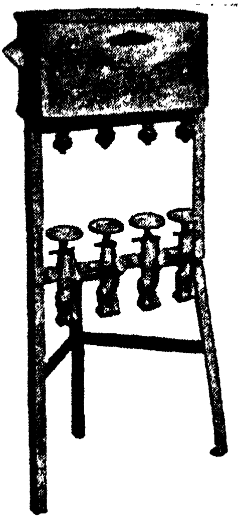


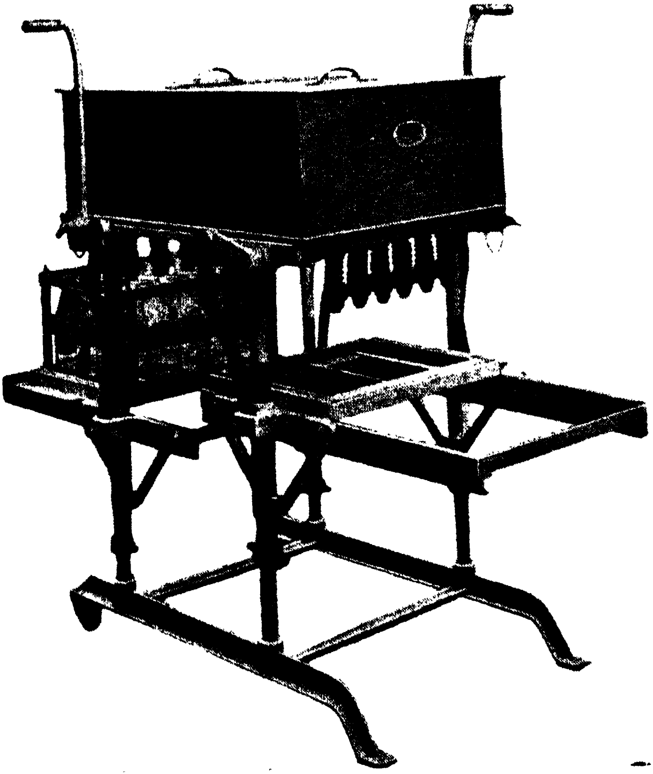
[*By courtesy of G. Hopkins & Sons Ltd.*

FIG. BF 4.—" *Multifiller* " *Quantity Filling Machine.*

FIG. BF 6.—3 *to* 4 *Valve Gravity Fillers*

[*By courtesy of Clares Ltd.*





[*By courtesy of Jas. Hamilton & Sons.*

FIG. BF 7.—*Scotia Bottle in Crate Filler, Type* 2.

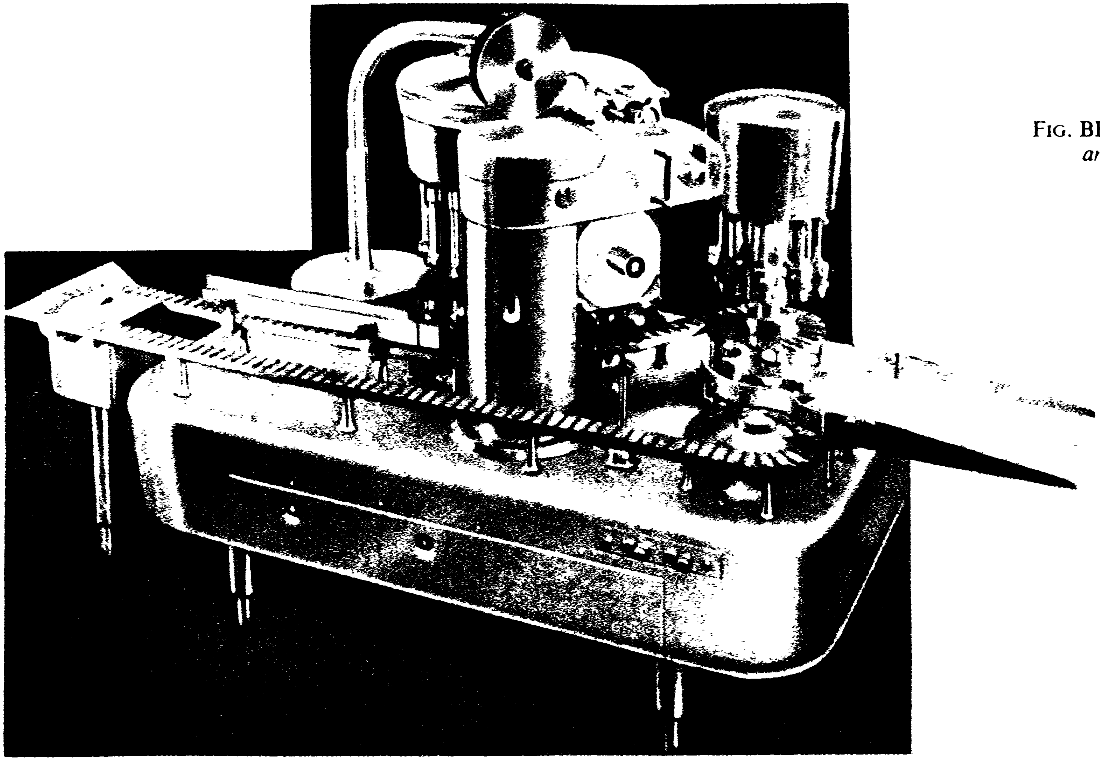


FIG. BF 8.—*Fully-automatic Filler and Aluminium Capper.*

[*By courtesy of U.D.E. Co.*

waterproofed it and delivered it to the filler and capper—a small carton factory inside the dairy itself. The whole process seemed so simple, logical, and what is most important, so clean, that one asks why it did not develop further. It removed from the dairy the handling of dirty bottles and the cost in power, chemicals, labour, and water in cleaning these. Transport costs were cut owing to reduced weight per gallon of milk in cartons as against glass and finally it was more hygienic. Bacteria counts taken in a large dairy where the cartons were made from the roll gave an unquestionable verdict in their favour and while comparable figures are not available for the pre-formed type of carton these must necessarily show a somewhat higher count than the other since they involve handling before filling.

Yet in spite of these advantages which the carton system can claim, the glass bottle holds its position. Its cost per bottle run, considering the figures given by some very large dairies in industrial areas over a period of years, works out at 0·3 to 0·35 pence per gallon of milk delivered, a loss of 16·5 bottles per 1000 issued and a life of sixty-one runs. (Regarding this question of how long a bottle lasts, the figures available vary from eighteen to sixty-seven runs depending on the nature of the trade the bottle serves.) Further, from the very important angle of cleanliness, bacterially that is, the average number of bottles showing counts of less than 600 organisms per pint bottle or 1 per c.c. of the bottles was 85 per cent. in many dairies while in others 70 per cent. showed less than 200.

It may fairly be claimed therefore that despite the seeming advantages the carton possesses, the glass bottle is not really so far behind even in the major point of cleanliness while it definitely beats the carton in actual costs. In view also of the present difficulty in the supply of pulp which comes for the most part from " hard currency " areas, another advantage is scored for glass and this state of affairs seems likely to persist for a long time to come. We feel therefore, considering all these points, that no apology is necessary if the subject be now confined to the filling and capping of glass bottles. (*See also* Cartons.)

Filling. The design of filling machines must take care of certain fundamental features whether the unit be of the smallest output capacity or one of the largest fully automatic giants dealing with upwards of 120 bottles per minute. These essentials seem to the author to be : (*a*) Robustness of construction. The component parts of the machine must be stoutly made to withstand the daily routine of dismantling, cleaning, and reassembly, all done at high speed and by labour more concerned with output than with the maintenance of the plant as such. (*b*) All parts of the machine must be readily capable of dismantling for cleaning and be so designed as to reduce to a minimum points where dirt, bacteria, or milk deposits are liable to lodge. (*c*) Metal parts coming into contact with milk should be chosen preferably to avoid any chemical reaction with or metallic contamination of the milk. In this respect suitable grades of stainless steel are almost universally used nowadays for milk vessels and pipe lines attached to fillers. (*d*) The cost of the plant must be related to the output desired. While keeping in mind that close attention to (*a*), (*b*), and (*c*) will tend to raise the cost of a machine, omitting to do so will result in frequently recurring heavy repair bills as well as loss of output during repairs. On the other hand, over-elaboration in producing a super machine may well place it, from the cost angle, beyond the power of the dairyman to obtain a commercial return on his investment, and any purchase of that sort means that he cannot replace his plant as frequently as the progress of the times may demand.

Passing now from these generalities, the next step is to examine some of the many types of bottle-filling machines available to-day. These are produced in a wide range of sizes, catering for the smallest dairyman handling 50 gallons a day, up to the largest designed for the commercial dairy and handling thousands of gallons per day. Two principles of filling are employed, one, by far the more general, being that of " level filling ". The other, " quantity filling " is in smail demand to-day, though some machines are still produced to operate on this principle. Its popularity, which at one time appeared to make this style general, waned considerably, with the progressive improvement in bottle manufacture towards greater uniformity of capacity. This enabled the more readily worked machine operating on the " level " principle to supply to each bottle a sufficiently accurate quantity to satisfy the authorities and the public. In describing the " level " filling machine as being more readily worked, we take into account that

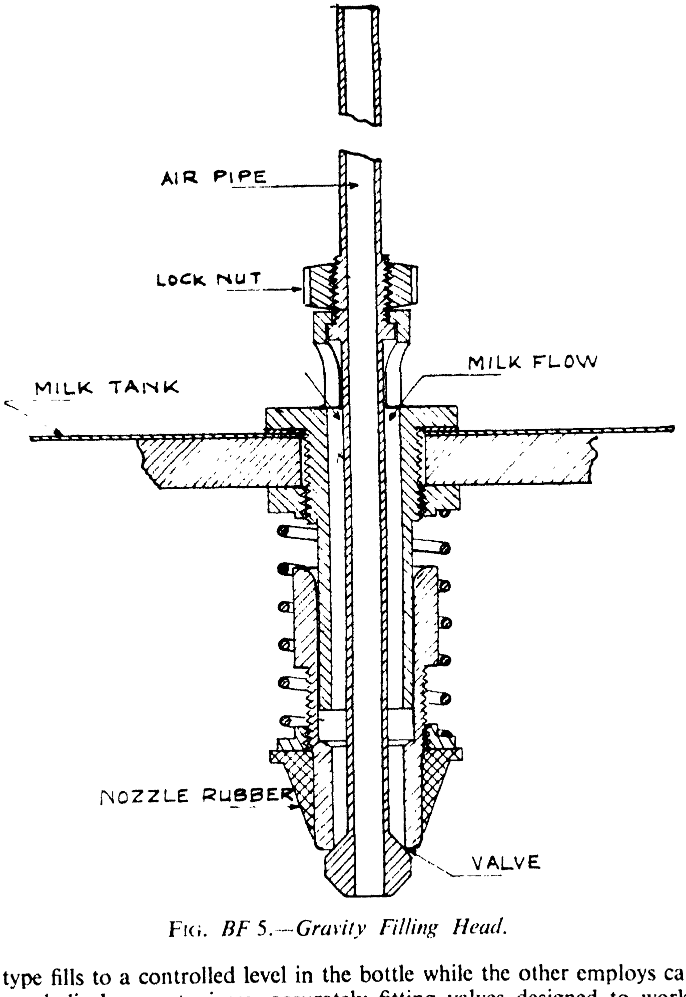


FIG. *BF 5.—Gravity Filling Head.*

this type fills to a controlled level in the bottle while the other employs capacity cups and displacement pieces, accurately fitting valves designed to work with milk controlled to a certain temperature and other more or less intricate parts, on the correct assembly of which depends the success of the filling operation. Failure to achieve this means inaccurate filling and it will be appreciated that not all dairies could, even if they would, maintain this standard continually and so " level " filling has become the generally accepted principle observed in modern design. But although measure or quantity filling has gone out of general use, especially for large capacity rotary machines, one make, Fig. BF 1, still enjoys a well-earned reputation. It is employed principally for sterilised milk bottles and cartons, and can give outputs up to 1800 bottles per hour. A model for dealing with bottles in crates is also available, shown in Fig. BF 2. This gives outputs up to 2800. These machines being entirely operated by hand, are particularly suitable for dairies where power is not available. Fig. BF 3 shows a power operated unit giving up to sixty-four bottles per minute.

The general working principle of these interesting machines is the use of a hand-operated, partially rotated block carrying four measures, in two pairs. These measures may be identical, *i.e.* all 1 pints or ½ pints, etc., or one pair in each head may be 1 pint, the other being ½ pint or other measure.

While one measuring chamber is filling from the tank the other of the pair is discharging into the bottle, and so by a partial turn of the measuring head by the handle the bottles are filled by alternate chambers. Fig. BF 4 shows a measuring head dismantled.

The simplest form of " level " filling machine consists of a milk tank mounted on a stand at a height of about 4 ft. from the floor. In the bottom of the tank are placed the filling valves, Fig. BF 5, numbering anything up to five. Below the valves or heads is a corresponding number of bottle rests built into a cross bar adjustable vertically to suit the height of bottle filled. On the bottle being lifted by the rest against the filling head, the latter being fitted with a rubber mouth-piece to secure a " seal " against the bottle mouth, the valve in the head is opened and milk flows down to the bottle by gravity, the air from the bottle meantime being discharged to atmosphere by a central pipe in the head to a point above the milk level in the tank. In this way an even flow of milk is maintained till the bottle is filled and withdrawn by lowering the table supporting it. Fig. BF 6 shows such a machine, typical of many makes by which bottles are filled individually.

The same method of filling is adopted in a useful type of machine which fills bottles in the usual dairy crates. In this style the filling heads are spaced to take one row of bottles at a time, and so a crate of clean empty bottles passes through the machine, the bottles being filled row by row. A natural development of this design was the double-ended machine.

This permits filling quarts at one end, say by means of four valves in line, making three operations to fill the twelve bottles, while at the other end five valves are fitted to fill the usual twenty-pint case. Such machines as Fig. BF 7 meet the requirements of dairies up to 200 to 300 gallons per day and, fitted with suitable capping machines, give a really useful output. Readily portable and requiring no power other than that of the operator they are eminently suitable for the farmer-dairyman.

For installations where mechanical power is available, the rotary semi-automatic filler or the fully automatic unit with capper incorporated was produced, giving outputs well beyond the capacity of the simpler machines. The valves are operated exactly as in the smaller machines and the milk is fed into the tank, also by gravity. Bottles are placed on bottle rests by hand, each head in turn, and the machine rotating delivers the filled bottles automatically to the capper from which they pass to the collecting table for loading into the crate. These small fillers are very compact, use only ½ h.p. to ¾ h.p. for outputs of 1400 to 1800 pints per hour and require two operators. Larger machines with up to eighteen heads step up the range of outputs to 5400 pints or 2700 quart bottles per hour. For outputs of 1800 pints per hour and over it is distinctly advantageous to have the bottle-feed mechanically operated. Generally this feed is of the slat conveyor type though different makers employ different types of feeds.

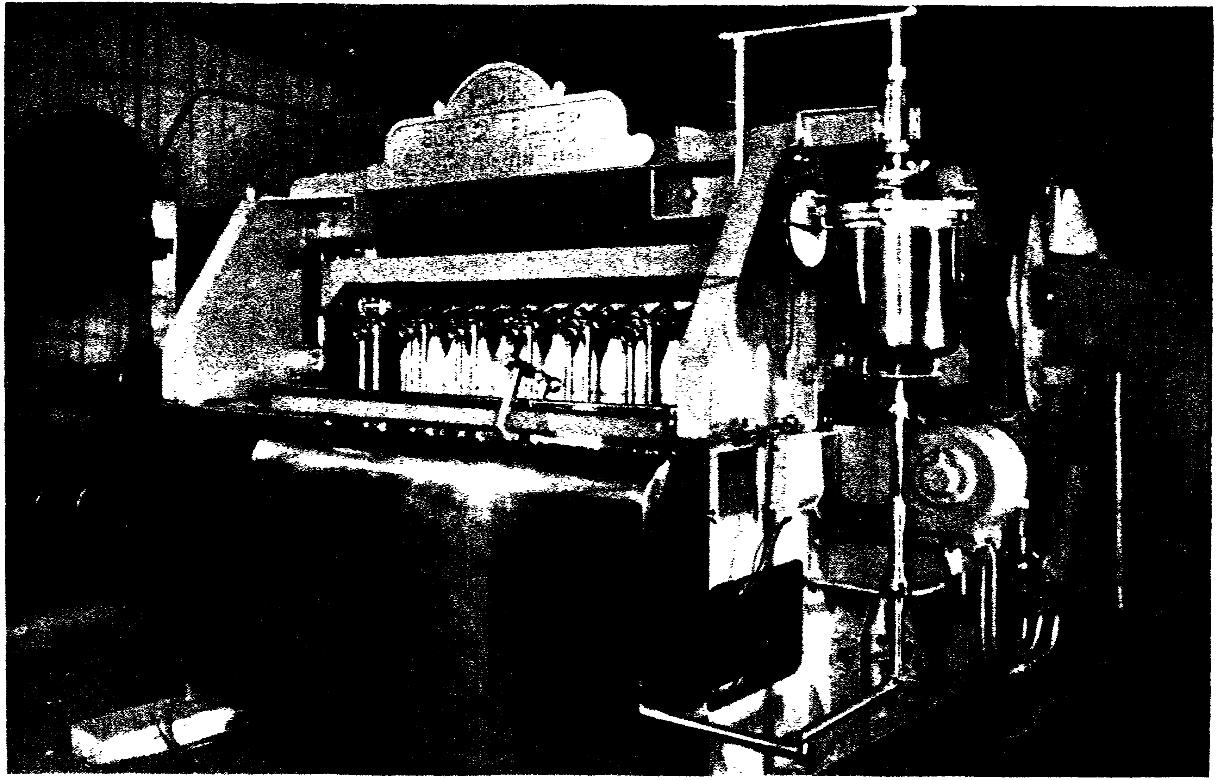
One disadvantage that the gravity fed machine has and which by its very nature cannot be avoided using gravity alone, is the heavy loss of milk which results when the filling nozzle rubber loses its new condition or fails to make an effective seal at the bottle mouth due to the mouth being chipped. On such an occasion the milk continues to feed into the bottle from the supply bowl and is shut off only when the bottle descending at the point of discharge causes the head valve to close. It will be appreciated, therefore, and especially where the chip is large that considerable losses can thus take place. Gravity filling machines are therefore all fitted with drip-trays or gutters to catch this spillage which, however, is not entirely lost. It is drained into a can and used as " process " milk. Nevertheless, considering the higher value of the bottled article, it represents a considerable waste, which was sufficiently great to warrant the introduction of the latest type or principle of filling.

This newer principle which had already been successfully applied to a wide range of commodities other than milk is known as " vacuum " filling. In contrast with " gravity " filling, this system, by creating a vacuum or negative pressure in the bottle sucks the milk into the bottles from a central supply. As in the case of the " gravity " machine, the filling head is fitted with a sealing cup or ring of rubber against which the bottle is lifted. Failure to make an effective seal at the mouth either due to worn rubbers, chipped bottles or distorted glass means that the vacuum necessary for the milk to flow into the bottle cannot be created and the bottle therefore passes round the machine empty. In a " gravity " machine, as already explained, any bottle lifted into the filling head is supplied with milk irrespective of the condition of the bottle mouth and the flow will continue until stopped by the valve closing on the withdrawal of the filled bottle. In the gravity machine also, not only will the milk flow while there is a bottle on the stand, but it will flow over the mouth top unless the rubbers and glass make a proper seal. Not so with the vacuum models. In these a defective seal at the bottle mouth due to whatever cause, results in an empty bottle coming round, if the defect is large enough to cause failure of vacuum ; or a partly-filled bottle, if the defect be smaller. In any case the attendant seeing the empty or part-filled bottle, can readily trace the cause and apply the remedy.

Obviously this method affords the means of saving an enormous gallonage over a period and while its opponents, firm supporters of the older gravity system, held that on the other hand, it caused rejection of too many really serviceable bottles, at the same time they have made the concession to its superior merits by producing themselves models working on this principle. Whereas before the last war only one practical application of this principle as applied to milk was available, the post-war era is marked by its general adoption by most of the leading makers in Europe and America, for their larger products especially.

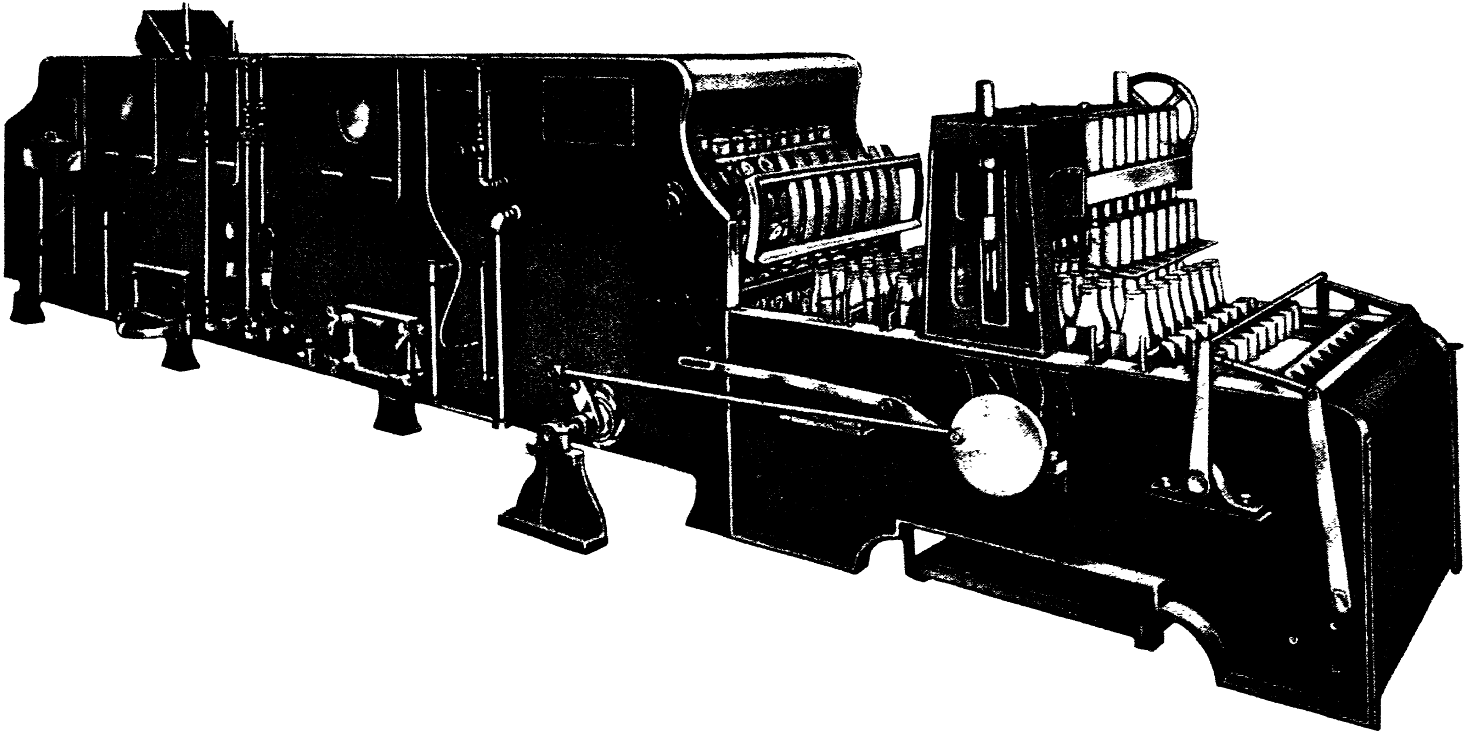
This last qualification brings us back to the essential features required in milk fillers, described earlier and referred to particularly in section (*d*). The introduction of the vacuum necessarily adds to the complications of the machine. The pump or exhauster, takes more horse-power, however small, and the air and vacuum ducts, and the automatic vacuum control are all extra points requiring attention. They could be described as elaborations resulting in higher costs of production. Consequently, dairy engineers apply vacuum filling to machines of outputs upwards of 300 gallons per hour which partly offsets these higher costs. Incidentally, by filling under vacuum, a higher rate of flow is possible. This also helps to make the machine cost less than otherwise it would, by securing a given output with fewer heads than the gravity system requires and so tends to balance the extra cost entailed by the additional apparatus called for.

In stating that these vacuum machines are limited to the larger models only and for outputs of 300 g.p.h. and over, it may be remarked that there are at least two prominent exceptions. One maker offers a machine of 2, 3 and 4 heads covering 40 to 100 g.p.h. for farmers who already employ vacuum equipment for milking. This machine has its milk bowl overhead on a stand and by vacuum this is filled direct from the milk churn. The arrangement is generally as shown in Fig. BF 6 which shows a gravity filler, except that the bowl is airtight. Hand operated bottle blocks lift the bottles against the filling heads, the outer position of which carries a sealing rubber and a return spring as shown in



[*By courtesy of Auto Dairy Engineers.*

FIG. BF 9.—14-*Row Vacuum Filler, Delivery End; showing Interceptor and Rotary Air Valve.*



[By courtesy of Dawson Bros. Ltd.

FIG. BF 10.—"*Hydrofilcap*" *Combined Washer, Filler, and Discer.*

Fig. BF 13. As the bottle rises against the sealing rubber, the valve is uncovered and the air in the bottle is extracted by the vacuum through the vacuum pipe to the milk bowl above the milk surface. When the bottle is exhausted of air to the same degree as the milk bowl, the milk flows down by gravity into the bottle. Fig. BF 13 is, in principle but not in detail, representative of most vacuum aided fillers. The other type of small-output straight line filler is actually valveless. It draws its supply by vacuum from a tank set lower than the filling heads. The vacuum is relatively high, 15 in. mercury, and in this respect differs markedly from most of the other vacuum operated machines. Its design makes it applicable, however, for such special duties as the filling of cream and evaporated milk. Single, double and four head models are available.

As to the general features of these larger filling machines, the bottles are almost invariably fed direct from the washer, using as short a length of conveyor as possible for this purpose. This is partly due to economy but is also to avoid undue exposure to air-borne bacteria. Feed wheels graded to suit the bottles pass them on to the bottle platforms, centralising them beneath the filling heads. Similar wheels remove the filled bottles on to the conveyor again and so they pass to the capping machines then to the accumulator tables for placing into the empty crates which meantime have passed along by conveyor from the loading end of the washer.

Most fillers, gravity and vacuum, employ cam-operated bottle tables but in one well-known make the conveyor chain itself passes the bottles round both filler and capper. In this machine the filling and capping heads themselves move vertically on a cam to allow the bottles to enter and leave the particular operation. The makers claim for this a steadier feed into the machine, an absence of rocking liable to occur when bottles pass over the dead plates separating the conveyor from the bottle tables, and a simpler mechanism for the feed which is also almost entirely accessible from above the machine. Fig. BF 8 gives an excellent view of this unit.

At least two other makers employ straight line fillers. These are built into and work in conjunction with automatic washers. They are made with the same number of heads in line as there are cups in the width of the bottle washer, from which it is separated by the shortest possible distance. This ensures absolute synchronising of washer and filler and minimises air infection. Fig. BF 9 shows the usual arrangement of such a combination.

The filling unit attached to this plant is worked on the vacuum principle and the bottles when filled are delivered by a cross conveyor to the capping or discing machine.

In the other make (Fig. BF 10), filling is done under gravity and the bottles are disced immediately after filling, there being as many discing as there are filling heads.

The majority of automatic machines feature pedestals controlled by cams, the filling heads being adjustable to suit the height of bottle and though rigid vertically, rotate with the machine. One make at least employs pressure for raising and lowering the bottle blocks, air being admitted by a series of ports in the stator, through suitable openings in the rotor which rides on it. Adjustment chokes in the air passages control the rate of rise or fall of these tables to fine limits while an ingenious arrangement of these chokes gives a " double drop " at the end of the filling which, under the vacuum employed, settles the filling height to a nicety. In this machine too, it should be remarked that other features include a completely valveless filling head (Fig. BF 11), the interceptor or vacuum chamber on top (Fig. BF 12) exhausting the bottle of air by the small vacuum pipes, whereupon the milk level maintained in each supply pipe at a height controlled by the external balance tank, rises to the head and pours into the bottle. This feature, which is also embodied in a combined washer-filler unit (Fig. BF 9), contrasts with many other vacuum fillers, in which the interceptor and float tank are combined and the filling heads are attached, as Fig. BF 13, immediately beneath. In these types some form of valve in the head is therefore necessary to prevent accidental loss of milk through failure of vacuum and more vacuum-capacity in the exhauster is required to overcome any little valve defects that inevitably result after the machine has been in use for some time. These are difficulties which are non-existent in the valveless type of filling head. The sealing rubber in this design is a flat ring held by friction into the head and is instantly removable for cleaning. The vacuum is of the " low " type and maintains 1½ to 2 in. mercury. In some models of this make, there is fitted an automatic vacuum control but in the newer range of machines, the pump is of such a design as to make even this control unnecessary. All the milk supply and vacuum pipes and tank work are of stainless steel and pipes made in straight lines for ease in cleaning.

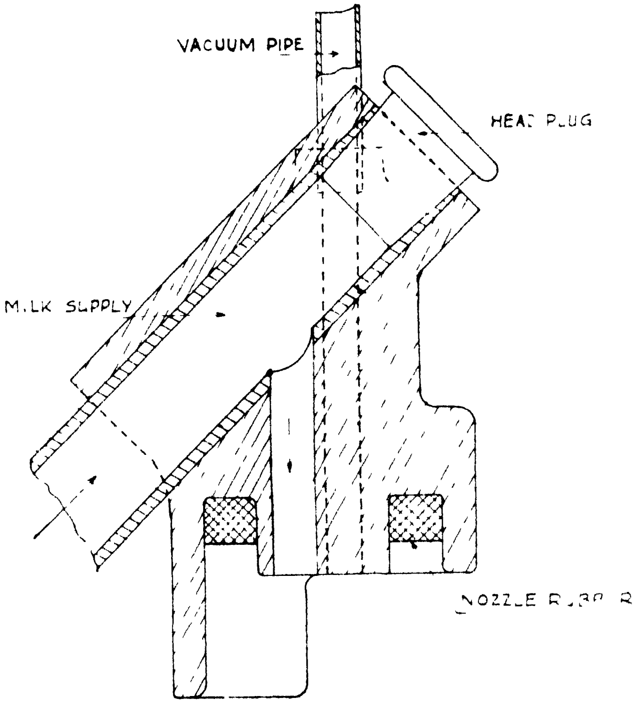


FIG. BF 11.—*Valveless Filling Head.*

This filler is available in two models, one as a filler alone, for linking up with any suitable capping machine and designed for either wide or narrow mouth bottles with the necessarily different filling head details for each of these types of bottles. The narrow mouth type is of course more used for sterilised milk.

The other model is a combined unit which fills the bottle and applies its own aluminium cap made by the machine itself from aluminium foil strip. Fig. BF 12 shows the combined unit which is manufactured in two sizes, a 15-head filler and 6-head capper with an output of 750 g.p.h. and 1000 g.p.h. model comprising a 20-head filler and 8-head capper. A smaller model is now announced carrying 10 filling and one capping head for outputs of 300-400 g.p.h. Fig. BF. 14 shows diagrammatically the principles of filling for both models and also the cleaning operation.

Some new continental models are announced of which one is now being manufactured in this country. These are all vacuum models and incorporate automatic cap-making and applying units. Two of them seem to be vacuum assisted fillers (the author has only seen photographs of these machines and judges them to be of that class) but the third is definitely of the full vacuum type, and of a novel construction. This machine has its vacuum exhauster on the top of the combined milk bowl and interceptor which is centrally placed above the bottle blocks. In the milk bowl, streamlined projections carry the simple filling head components. When in position each head is covered by a bell integral with a special plate covering all the heads and dividing the filling or milk bowl into top and bottom sections. Ports in the bell plate and also in each bell itself allow the vacuum to operate the filling process by raising the " rest " level inside the bell when the rising bottle has sealed the outlet end of the filling nozzle, to a point where the milk floods over the head and down the annular space between the central vacuum pipe and the outer nozzle into the bottle. Fig. BF 15 shows the whole machine and Fig. 15B the filling operation in five stages and also details of the filling head.

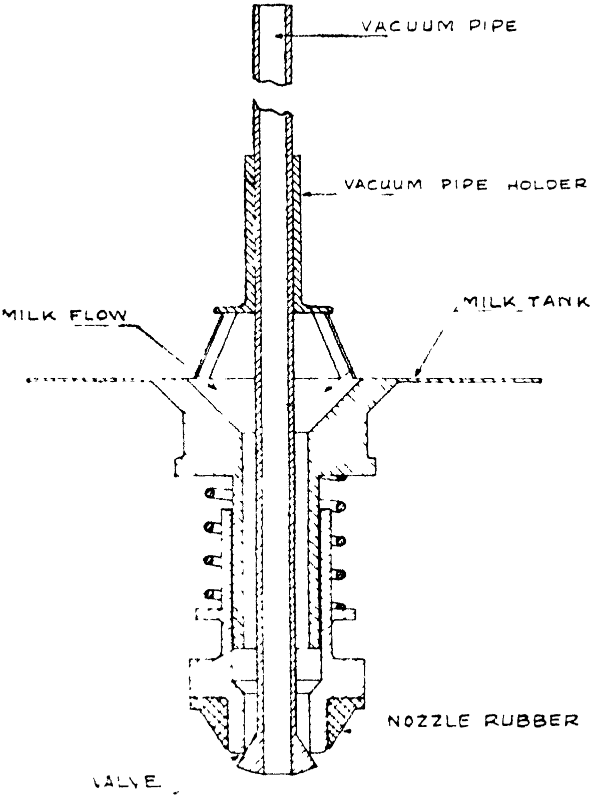
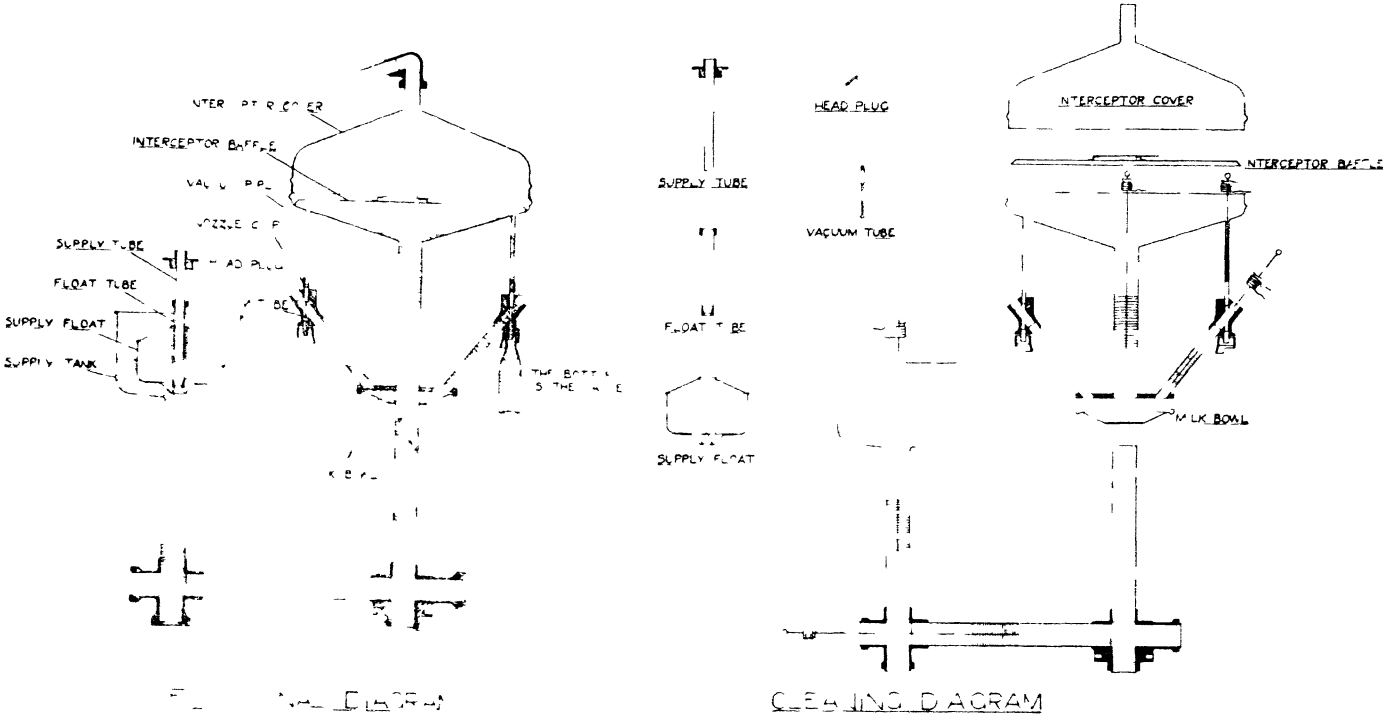


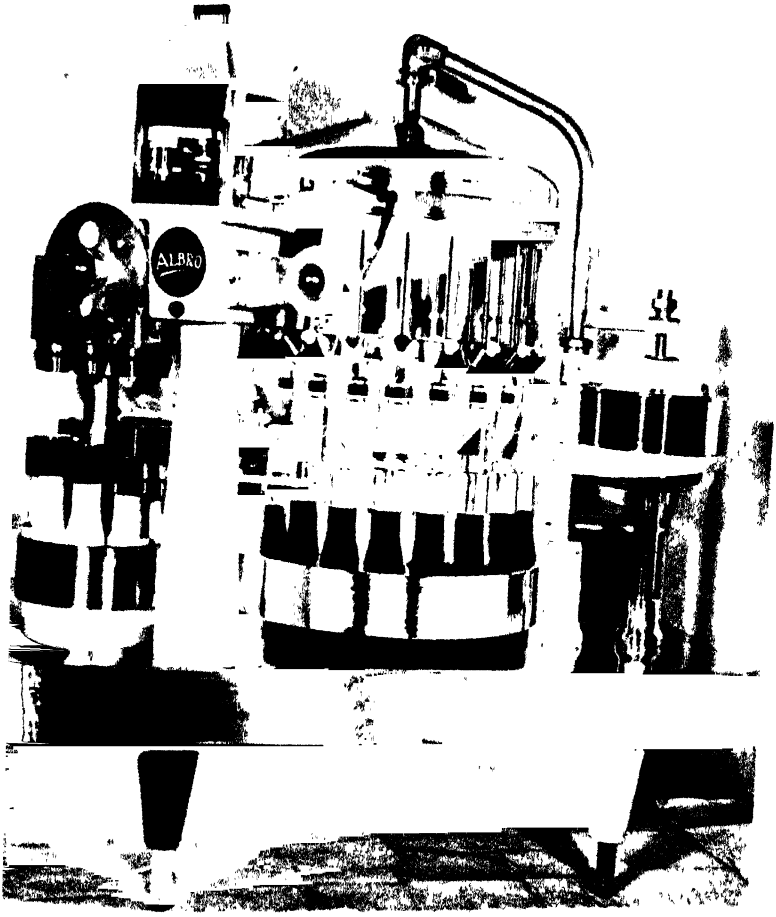
FIG. BF 13.—*Vacuum Filling Head.*

Other points claimed by the makers are air pressure lifted bottle blocks for filler and capper with a travel sufficient to allow a full range of bottle sizes to be used without employing lifting gear. Should this air pressure fail or fall below a certain minimum the machine stops automatically until the pressure is regained.



[By courtesy of Albro Fillers & Eng Co, Ltd

FIG BF 14 —*Diagrammatic Details of Filler*



[By courtesy of Allbro Ltd

BF 12 — *Combined Vacuum-operated Filling Machine and Aluminium Capping Machine. Output 1000 gallons per hour on pints.*

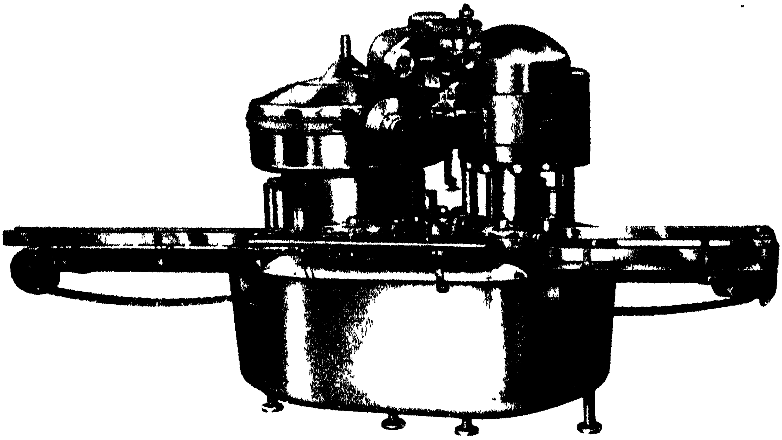


FIG. BF 15. *Sixteen-head Auto-filler and Capper*

[*Photos by courtesy of Alka, Sweden*

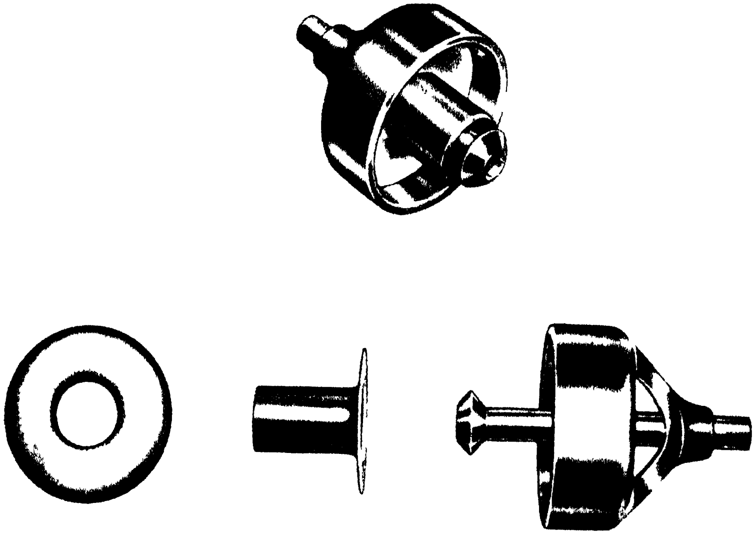


FIG. BF 15A.—*Filling-head Details*

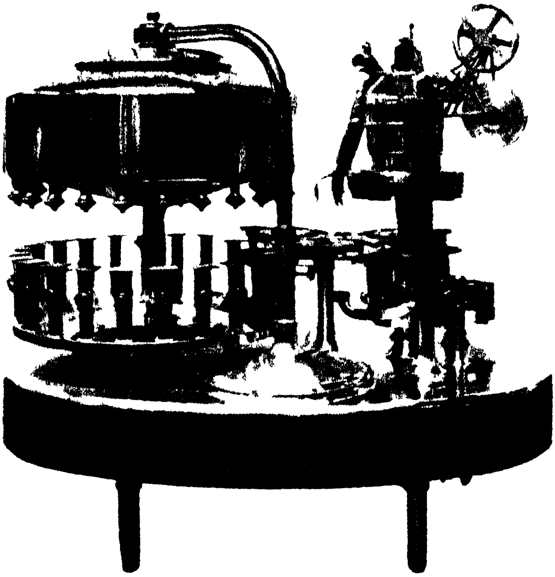


FIG. BF 16 *Twenty-four-head Filler and Eight-head Aluminium Capper. Fully Automatic*

[*Photos by courtesy of Graham Enock Mfg Co Ltd*

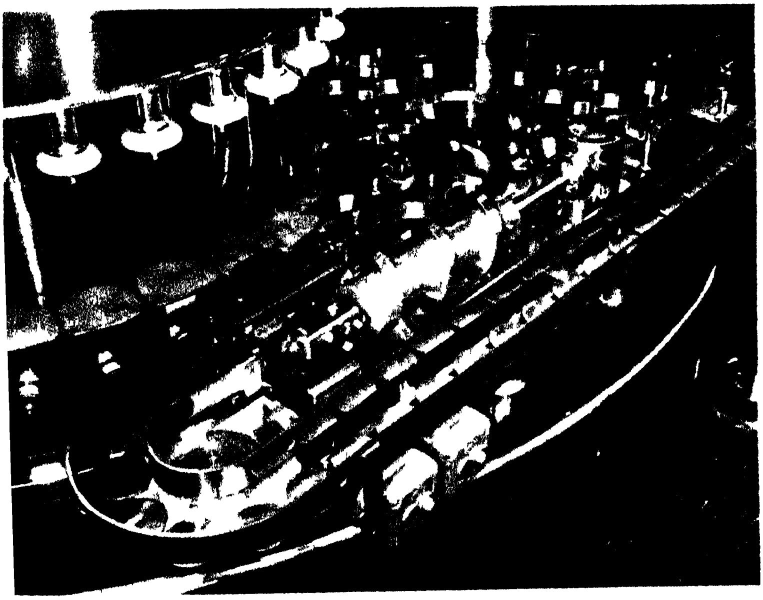


FIG. BF 16A *Details of New Screw Feed for Automatic Milk Filler*

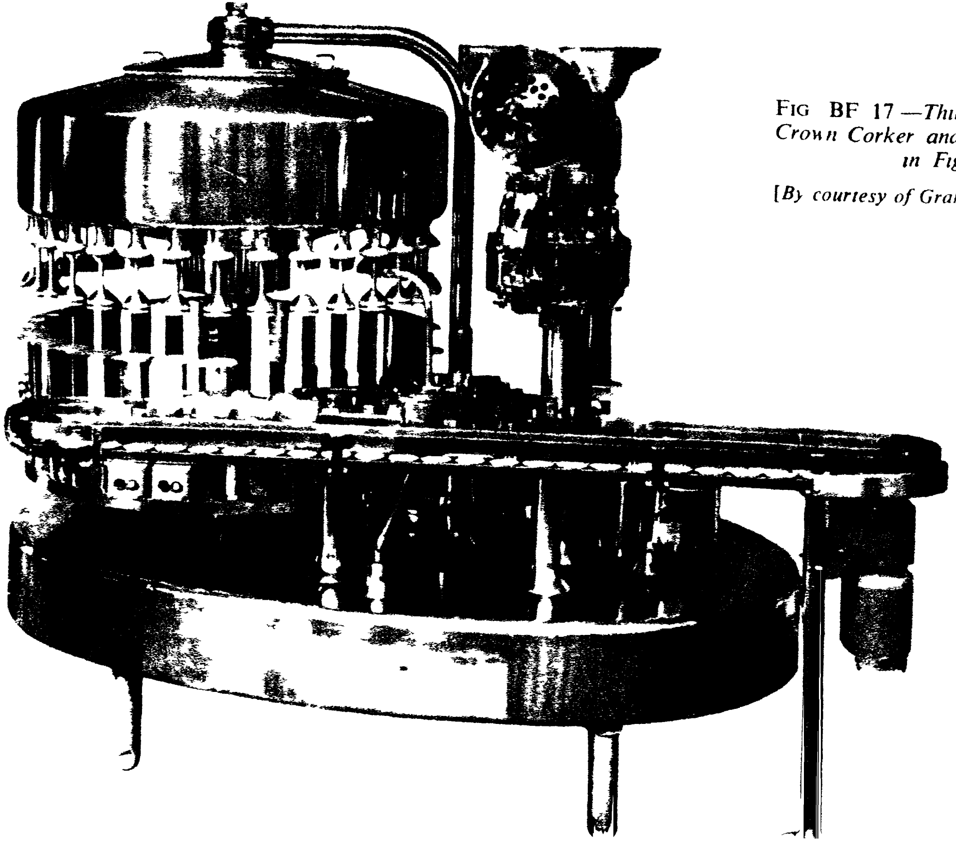
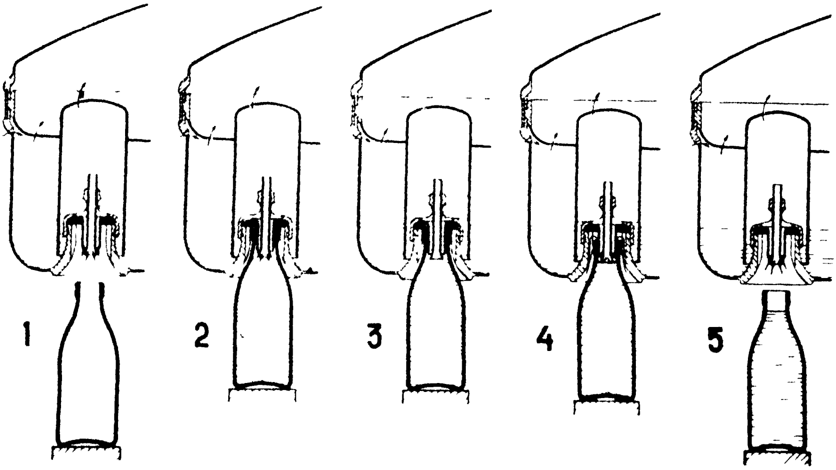


FIG BF 17—*Thirty-two-head Filler with Crown Corker and Screw Feed as shown in Fig BF* 16A

[*By courtesy of Graham Enock Mfg Co Ltd*

The machine is fitted with 16 filling and 8 capping heads and arranged for an output of 1320 g.p.h. A smaller unit gives 1050 g.p.h.

A further example of foreign design of machine is illustrated in Fig. BF 16. This is a notable case of international team work between British and American designers. At first glance it appears very elaborate indeed and the stainless steel casing, vacuum and milk supply pipes convey the impression of extravagance in design inevitably resulting in higher costs than the more usual designs would call for. The makers claim, however, that the design achieves such economies in construction even avoiding the cost in applying and waiting for drying the numerous coats of enamel generally given to high grade machinery, that the whole unit, including the capping apparatus, can be produced at a really economic price. In contrast also to other vacuum fillers this machine employs a rather higher vacuum than usual, as high as 13 to 14 in. of mercury. This vacuum is produced by a special pump embodied in the casing of the machine and fully accessible on the removal of the vacuum pipe and large diameter cover shown in the illustration. The bottle blocks or tables it will be noted are cam operated. Other interesting features in this production are the elevation of milk bowl and capper in one operation by electric power. Fig. BF 17 shows also an excellent design of combined filler and discer operated under gravity, produced by the same firm.



[*By courtesy of Alka, Sweden.*

FIG. 15B.—*Filling Operation in Five Stages.*

Other continental designs are shown in Figs. BF 18 and BF 19. In the first is shown a vacuum aided filler designed for coupling up by slat conveyor to a suitable capping machine. The exhaustor is clearly seen as a separate unit apart from the machine. Filling heads are interchangeable. That is, one filler can handle wide mouth or narrow neck bottles by changing the heads. The range of models covers 8 heads to 32, dealing with 450 gallons to 1100 g.p.h. in wide mouth pint bottles.

The further model Fig. BF 19 shows a vacuum aided rotary filler and capper combined for wide neck bottles and for outputs up to 7000 bottles per hour.

A vacuum filler working directly from the churn is shown in Fig. BF 19A.

In the foregoing brief descriptions of these various machines it should not be taken that they cover all the makes available. Those described have been selected as typical of the latest practice in filling and, where necessary, emphasis has been given to outstanding features. It is hoped that the survey will be of assistance to the dairy student and to the dairyman who may wish some guidance to enable him to assess what machine will best meet his needs.

The following table may serve as a catalogue of machines in general use in British dairies to-day, and reference to the makers listed will afford more extended information about each make than this article can possibly provide (p. 95).

Capping. Following immediately the subject of filling the milk bottle comes the equally important one of sealing it when filled, the types of closures available and the apparatus necessary for applying them.

With the general adoption of the glass bottle the cardboard disc rapidly became the favourite seal. Impregnated with wax it acquired at once a firmness for handling and a resistance to pulping ; it was ideal for rapid mechanical application in a machine, it could be artistically decorated by the printer and so had an advertising value, while its cheapness allowed it to be used once, when it could be discarded without loss. Packed in cylinders of 500, these discs can readily be stored in a dust free condition and when required for use are emptied into the special metal tubes or magazines generally attached to discing machines, all without handling.

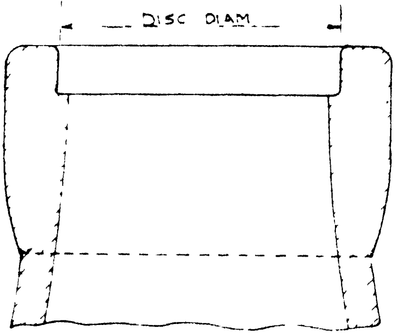


FIG. BF 20.—*Disc Mouth.*

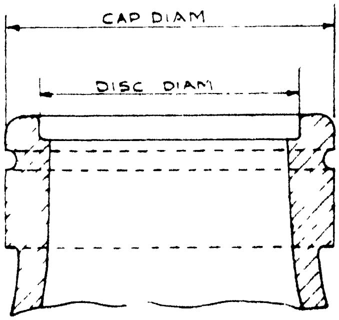


FIG. BF 21.—*Dual Purpose Mouth.*

Discs are generally made to standard sizes 42 mm. diameter and 0·7 mm. thick, though there is also a smaller disc supplied 35 mm. diameter. The larger, and by far the more common size, is for the ordinary range of bottles covering ⅓ pint, ½ pint, 1 pint and 1 quart. Fig. BF 20 illustrates one style of mouth for this disc. The smaller disc is used more by the farm bottlers among whom the " dual purpose " bottle has a considerable vogue. This bottle has a recess in the inside of the mouth to take the small disc while it is also fitted with a ring on the outside for an aluminium cap, the diameter of which is usually 44 mm. Fig. BF 21 shows the mouth of this bottle in cross-section. On account of this double grooving one may criticise the bottle for lacking glass and therefore strength at the most vulnerable point in a milk bottle. This design of bottle was developed to meet the requirements of the dairyman who deals with various grades of milk. For some of these grades, the ordinary type of cardboard disc is suitable while for others, where the bottler is required to cover the lip of the bottle, the aluminium cap is most suitable. This model, therefore, serves the " dual purpose " of discing or capping, the cap being usually 44 mm. diameter which is considerably larger than the usual size, and the disc 35 mm., which of course is 7 mm. smaller in diameter than the standard disc.

The removal of the cardboard disc once applied caused a little concern at first and many " gadgets " came on the market for the purpose of easing the operation. Quite a few included tabs attached to the disc by wire staple as Fig. BF 22 and these command a steady market. Although most useful, they do not seem to

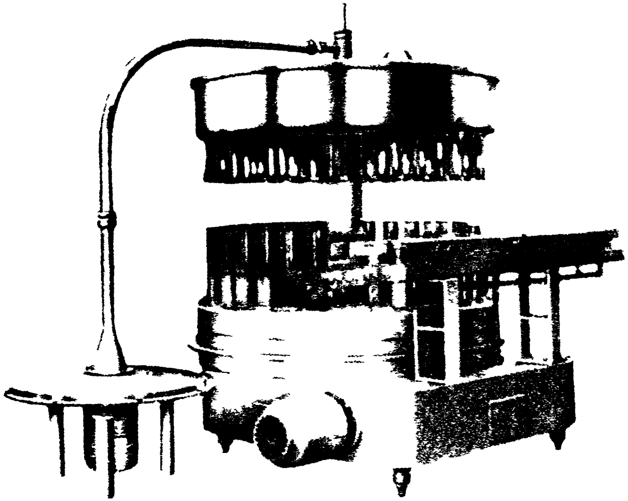


FIG BF 18 —*Dutch Design of Independent Vacuum aided Filler Note Exhauster*

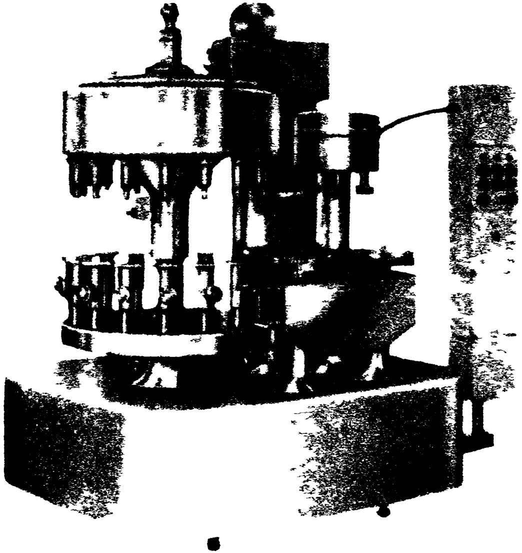
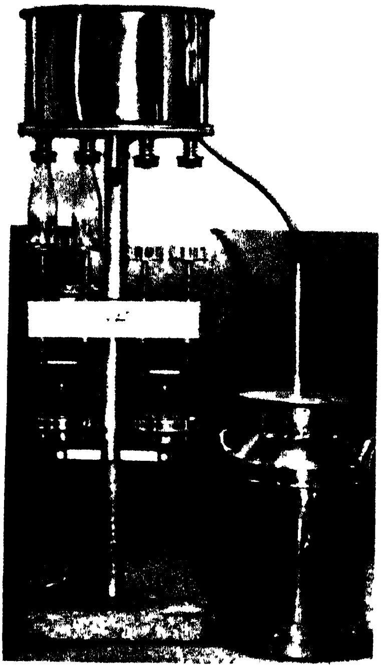
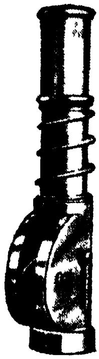


FIG BF 19 —*Dutch Design Vacuum Filler and Aluminum Capper*



[*By courtesy of Gascoignes (Reading) Ltd*

FIG. BF 19A.—*Vacuum Filler Working Direct from Can.*



[*By courtesy of The Dairy Supply Co. Ltd.*

FIG. BF 23.—*Discer.*

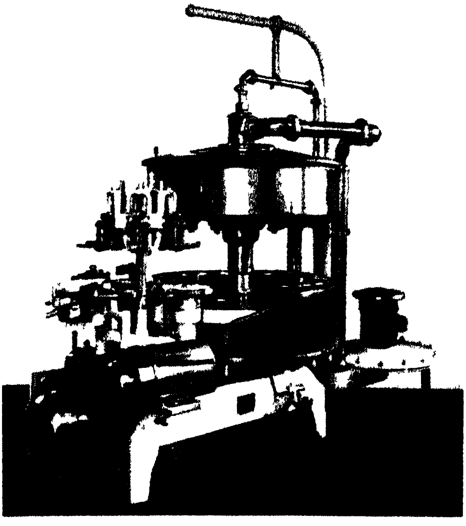
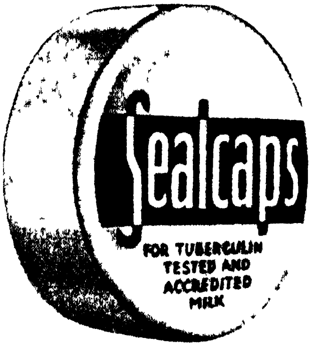


FIG. BF 25.—*Complete Cherry-Burrell "E.G." Gravity-Vacuum Milk Bottle Filler and Capper. Smaller models are available with gravity feed only.*



[*By courtesy of Smith Bros. Co Ltd*

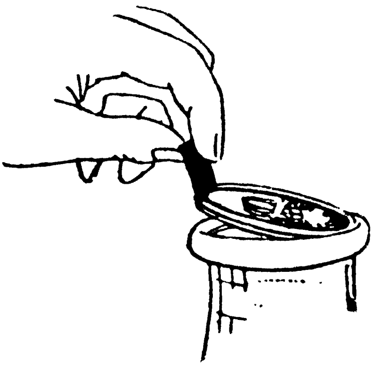
FIG. BF 26.—*Sealcaps.*

Name and address of maker	*Type of machine*	*Output*	*Ref fig in text*
Albro Fillers & Eng Co Ltd, Wharf Road, Ponders End, Middlesex	Albro" Vacuum Automatic Fillers for pasteurised or sterilised milk, 10, 15 and 20 head automatic Fillers and Cappers 1-4 head semi-auto fillers for cream and evaporated milk	300 1000 g p h –	BF 11, 12 14 –
Alka, Ltd, Alka Works, Minerva Road Acton, London, N W 10	"Alka" Vacuum Filling and Capping Fully Automatic Units	1050-1320 g p h	BF 15 and 15A
Auto Dairy Engineers, Palace of Industry, Wembley, Middlesex	"A D E" Combination Hydro Washer Vacuum Filler and Capper	Consult makers	BF 9
Clarke Built Ltd Power Road Chiswick London W 4	EG EGV, Gra Vac Automatic Vacuum Rotary Fillers and Cappers	540 1800 g p h	
Clares, Ltd, Wells, Somerset	3 4 Valve Gravity Fillers	1000 bottles per hour	BF 6
Geo S Clayton, Ltd, St Anne s Street, Limehouse, London E 14	Clayton 4F Semi automatic 4 head Filler 1 head Capper Clayton 10 FV Fully Automatic 10 head Filler 4 head Capper	175 225 g p h 225 450, 625 g p h	
Dawson Bros, Ltd, Gomersal, Leeds	"Hydrofilcap" Combined Washer, Filler and Discer	100 1000 g p h	BF 10
Dairy Supply Co, Park Royal, London, N W 10	"Desco" Fillers 4 valve Gravity Fillers		
Graham Enock Manfg Co, Ltd, Windus Road, London, N 16	"Gem Cemac Vacuum Filler and Capper Unit		BF 16, 16a, 17
Jas Hamilton & Sons Gallowgate, Glasgow, E 1	"Scotia" Bottle in Crate Filler	100 300 g p h	BF 7
Hans Hanover Co, Soborg, Copenhagen	Titan" Automatic Filling and Capping Units		
G Hopkins & Son, Ltd, 40-52 Holloway Road, London	"Multifillers" Quantity Filling Machines		BF 1, 2, 3, 4
Perkins, Ltd, Mansfield Rd, Derby	Gravity Fillers and Cappers semi-automatic	100 360 g p h	
U D E Co Ltd, Abbey Works, Cumberland Avenue, Park Royal, London, N W 10	Fully Automatic Filling and Capping or Discing Units Vacuum	250-1500 g p h	BF 8

Name and address of maker	Type of machine	Output	Ref. fig. in text
Vipan & Headley, Leicester	" Wyvern " Hand or " in crate " Single and Double-ended Fillers	100-300 g.p.h.	
N.U. Marja, Konigsweg 2A, Utrecht, Holland	" VV " Vacuum Filler and Capper	450-1100 g.p.h.	BF 18
Geo. Stork & Co., Apparatenfabrick N.V., Amsterdam, Holland	Vacuum Filler and Capper V.C.	7000 bottles per hour	BF 19
Gascoignes, Reading	Vacuum Fillers for farmers	350-800 pints per hour	—

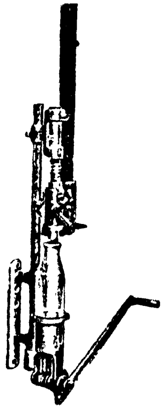
lend themselves to rapid automatic handling, although discing machine makers claim they can be worked equally as well as the plain disc, as the attachments sometimes tend to lock together and for commercial dairy use they are perhaps not so much in evidence partly due to these mechanical difficulties and probably also to the extra cost involved.

Another type of disc, with semi-cut circle, is, however, in great use to-day. On depressing the circle an aperture is exposed which allows the insertion of a suitable tool, to remove the disc, or, in the case of ⅓ pint bottles so generally used for school milk, offers a very convenient entry for the suction straw issued with each bottle. This disc also, having a perfectly flat surface on each side, is quite as suitable for machine application as the plain type without the aperture.



[*By courtesy of Waxed Papers Ltd.*

FIG. BF 22.—*Tabbed Discs.*



[*By courtesy of Vipan and Headley*

FIG. BF 24.—*Discer.*

The application of the disc to the bottle is very simple. For small bottlers using 2, 3 or 4 head single bottle filler there are available some types of hand operated magazine discers shown in Fig. BF 23. The vertical column holds a portion of a tube of discs, one of which is normally lying in the throat. By placing the tool on to the bottle and depressing the magazine against the spring, the disc is rammed home into the bottle neck. When pressure is released a trigger feeds the next disc into the throat ready for the next application. Similarly, machines holding a tube of 500 discs and operated by a horizontal sliding shutter can be mounted at the side of the filler. An example of this is given in Fig. BF 24.

For larger outputs the rotary discer was introduced. This operates generally by spring and cam movement in the bottle block, and raising the bottle into the discing head drives the disc into the bottle neck in the same way as does the smaller single unit. The speeds of operation for the rotary discers vary somewhat with the make of machine but generally an output of 1000 to 1100 bottles per hour per discing head is achieved. Fig. BF 25 gives an excellent illustration of these rotary discers working automatically and in conjunction with rotary fillers, with which they are mounted on a common frame.

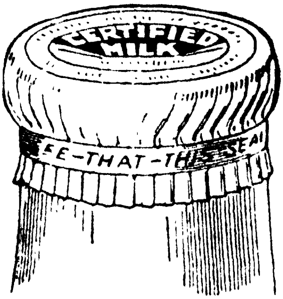
Leaving the subject of discing now, we pass to some types of special closures. Although the disc represented a very satisfactory type of closure for general use advancing study of milk and milk requirements called for an even higher efficiency in closures. Hygienically the disc-closed bottle was found to fall short of ever advancing standards of cleanliness, and with the introduction of Graded Milk, " Milk (Special Designation) Order, 1936 ", more complete seals were required which would cover the bottle mouth entirely. This affords a protection from rainwater, hand contamination during delivery, and the piercing of the exposed disc by birds or animals, to say nothing of tampering by humans. The well-known crimped paper cap for a long time met requirements for these Graded Milks. They were slipped over the already disced bottle and secured by a ring of tin alloy. These have now largely been replaced by snap-on caps made wholly of paper and they are applied by hand or pressed on by a simple tool. Another crimped paper cap in general use is secured round the neck by adhesive paper strip. A special machine is available for applying the tape. Both these types of caps are illustrated in Figs. BF 26 and 27 together with the taping machine, Fig. BF 28.

In the bottling of Sterilised Milk a narrow mouth bottle is generally employed. As a seal for this type, the swing stopper, once a favourite in the aerated water trade but now falling out of use, plays an important part. The body of this stopper being made of porcelain, the seal between it and the glass is effected by a rubber ring. The closure is attached to the bottle by a galvanised steel wire loop which when the bottle is being filled lies at the side of the neck. After the filled bottle leaves the machine, the stopper is lightly inserted into the bottle, the loop pressed down and the closure securely fastened. Its removal is effected by pressing the loop in the reverse direction. No tools are necessary for this closure.

Another type of closure in common use, specially for Graded Milk, is the crown cork, also a universally used closure in other bottling trades. This is made of lacquered tin plate, the outer surface being suitable for decoration and the inner surface lined with a waterproofed paper lining. Made in three sizes crown corks are suitable for narrow mouth bottles as used for sterilised milk, 26 mm. diameter, medium size, 36 mm. diameter and large size 42 mm. diameter for the wide neck bottle. These are most secure, closures and meet the requirements of the various Milk Orders issued.

The crown cork is a most suitable closure for automatic handling and beyond feeding the hopper shown at the top of Fig. BF 29, it is not touched by hand till the bottle is being loaded into the crate. This Fig. shows a very popular, fully automatic crowner with self-contained motor drive and eight capping heads. In the hopper the crowns, kept in gentle motion by an agitator, are sorted by a selector wheel and fed, right side up, into the chute leading to the crowner throat. There the head descends on the bottle, crimping the wavy skirt of the crown into the external ring of the bottle mouth and makes a perfectly secure liquid tight seal. This machine is capable of dealing with up to 6000 bottles per hour but having eight heads the rate of movement per head is quite low, ensuring a successful finish to the operation with minimum wear in the working parts. Other machines for lower outputs are marketed giving various capacities down to that of the single head machine working at anything up to 1800 bottles, pints, per hour (Fig. BF 30).

Crown corks can thus be considered under two categories, viz.: (*a*) those of suitable size (26 mm. dia.) for use on the comparatively narrow necked bottles employed in the packaging of sterilised milk. For this purpose it has, in the past, been customary to use the standard type of crown cork (with cork insert) which has proved to be a most satisfactory closure for withstanding the conditions encountered during in-bottle sterilisation. With a view to reducing costs, however, there has recently been introduced on the market in Britain a lightweight crown-cork known as the Milcrown. This closure is understood to fulfil all the essential requirements of the crown-cork in dairy bottling performance, with the additional advantage of an appreciable reduction in cost. (*b*) Those of larger size (from 36 mm. dia. to 45 mm. dia.) for use on the wider-mouthed bottles employed in the packaging of pasteurised and other milks. There is a variety of types of closure available for use under this category. Among the higher class (and correspondingly more expensive) types of pre-formed closures, are the Milcro seal and the Dacro seal, together with the P.38 closure—this last mentioned being available at present only in America. These three seals are all of similar construction, namely, an outer shell of comparatively lightweight metal (usually tinplate or aluminium) to which is bonded an interior lining of paper-board. All are capable of application by automatic methods, the main difference between them being in size, viz., Milcro 36 mm. dia., Dacro 45 mm. dia., P.38 38 mm. dia. Though the cost of these seals is comparatively high they have an established "customer-appeal" and their use is frequently found to be advantageous, particularly where high speed high-efficiency bottling plant is involved. The use of pre-formed closures of this type, coupled with the less intricate and more sturdy closure-applying machines, has often produced benefits in increased efficiency which outweigh the higher cost of the seals when compared with the operation of machines which form caps from rolls of strip-metal.



[*By courtesy of Fords (Finsbury) Ltd.*

FIG. BF 27.—"*Kovercap*" *Bottle Seal.*

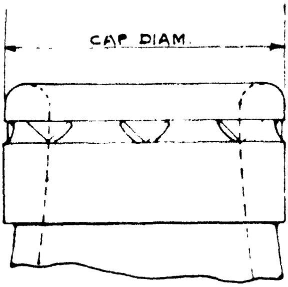


FIG. BF 33.—*Special Aluminium Cap Mouth.*

It would appear that though these new closures may be relatively expensive compared with discs or aluminium caps, due to the more costly nature of their make up, the advantages claimed for them seem likely to be substantial. These include the saving in first cost of expensive aluminium cap-making machinery, generally attached to the capper in automatic filling units; and the cost in care and maintenance of this machinery which is a most intricate engineering unit demanding a fairly high degree of accuracy and also, therefore, skilled attention. There are doubtless good grounds for these claims and it is more than a pity that a year or two seems likely to elapse before they can be put to the test in this country.

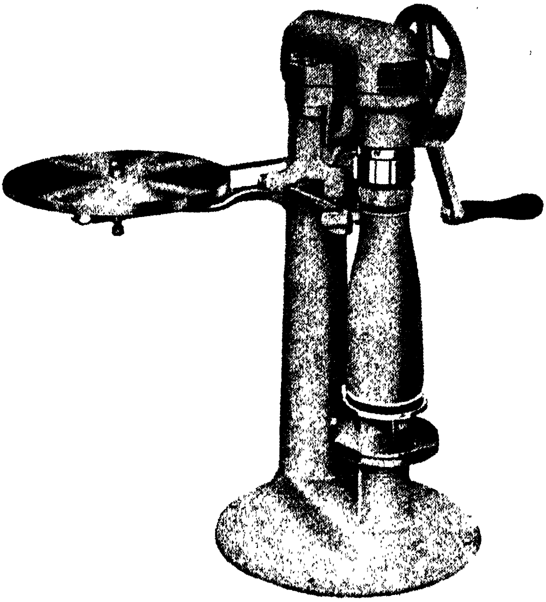
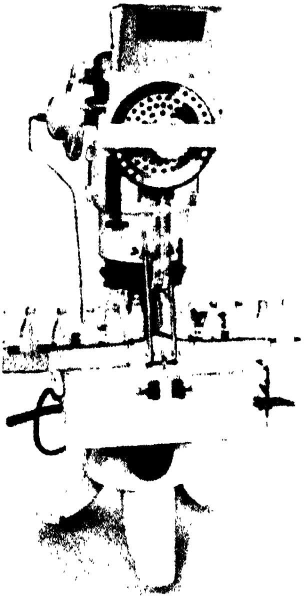
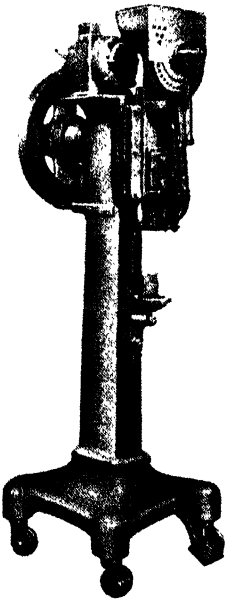


FIG. BF 28.—*Taping Machine.*



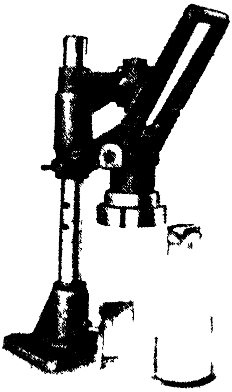
[*By courtesy of R. W. Webster and Co. Ltd.*

FIG. BF 29.
Crown Corking Machine.



[*By courtesy of The Crown Cork Co. Ltd.*

FIG. BF 30.
Crown Corking Machine.



[*By courtesy of The Dairy Supply Co Ltd*

FIG BF 31.

" *Desco* " *Aluminium Capping Machine*

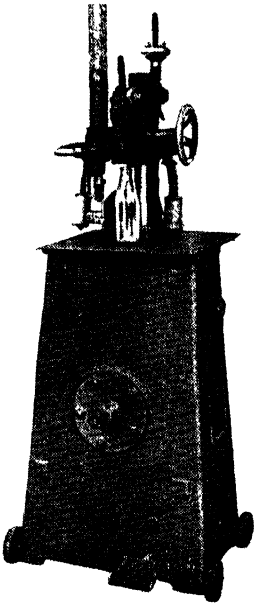


FIG BF 32

"*Alka*" *Discer Capper*

[*By courtesy of Alka Ltd*

The next closure to be considered is the aluminium cap, made from polished aluminium strip of thicknesses varying from 0·005 in. to 0·0065 in. It is an excellent material for stamping to the shape required, can be pressed readily into the ring round the bottle mouth, is a safe metal for contact with milk and is very cheap. A further advantage it possesses is that in one operation it combines the security of the disc with the hygienic covering of the paper cap and so meets the requirements of the dairy laws of 1936. A variety of sizes are available suitable for bottles ranging from 34 mm. to 44 mm. mouths. Except for the 44 mm. size which is designed for the " dual purpose " bottle described at length earlier, the other sizes are for bottles using only aluminium closures.

For the smaller bottler whose output does not justify the heavy expense of an automatic stamping and capping machine, these closures are marketed as finished caps and stamped with the dairy's own die if desired. For such dairies these caps have to be slipped over the bottle mouth by hand, the closing pressure being applied by a simple hand tool or by a bench tool as in Fig. BF 31. The operating medium is an internal rubber ring which presses the cap into the groove of the bottle mouth. These caps, however, having been placed by hand on the bottle cannot be used for T.T. Milk. For this the fully automatic capper, stamping out and applying the cap to the bottle without handling, must be employed. There is, however, available a semi-automatic capper which will feed preformed caps from tubes each containing 1000 caps direct to the bottle and seal them, all without handling. This will meet the needs of the dairy whose output cannot justify the fully automatic model, and it allows the use of this closure for T.T. Milk. Fig. BF 32 shows the machine very clearly. At the side of the capping head the tube of caps is plainly visible. The caps are withdrawn from the tubes and transferred to the capping head by a current of air from a pump in the machine when, on depressing the foot pedal, the seal is applied (Figs. BF 34 and 35).

Most aluminium caps are supplied as plain circular closures but as in the case of the cardboard discs ways and means of opening them required attention so these caps developed side tabs. This device is stamped out integral with the cap and is pressed flat against the glass by the closing tool. It is a feature available for pre-formed or strip formed caps and is very efficient. Whether it will work equally well with the semi-automatic machine, Fig. BF 32, the writer cannot say. It certainly limits the range of cap forming machines to those that transfer the cap to the closing head in a horizontal plane. Those machines in which the chute is on a vertical plane so that the cap rolls on its edge to the capper, must use the round cap without this tab. To meet this difficulty, another type of opener was introduced, this time on the bottle neck itself. Certain makers have produced a bottle with the standard cap ring but, in addition, this ring has small triangular or V-shaped ridges vertically across the groove. The cap applied need only be partly turned by hand when these ridges open out the cap skirt and so loosen the whole cap from the bottle. Fig. BF 33 shows this style of bottle mouth.

By far the largest number of aluminium caps used are made and fitted to the bottle by automatic machines built into the framework of the filling unit. The caps are made from aluminium metal foil of just sufficient width to produce the cap circle with or without the side tab described earlier. The roll of foil is placed on a spindle and a certain length fed through to the discs, passing through on the way a pair of small rolls where the strip is oiled lightly with a neutral oil. This acts as a cutting compound, preventing heating of the dies and so reducing wear, as well as ensuring a cleaner stamping. The feed to the dies is done with a variable stop-and-start motion, allowing the strip time to stop while the die punches out the shape, leaving the cap beneath the strip. From there it is generally removed by a jet of air which blows it over to the feed slot in the capper head in one make of capper. In other makes it passes to the end of a small conveyor where it hangs, one edge down, ready to catch on the mouth of the bottle which at the moment is passing beneath it and which, with the cap now loosely placed on top, travels to the capper.

Makers	*Closures or machines*	*Text ref. no.*
Albro Fillers & Eng. Co. Ltd., Wharf Road, Ponders End, Middlesex	Auto Fillers and Aluminium Cappers	BF 12, 14
Alka Ltd., Alka Works, Minerva Rd., Acton, London, N.W. 10	" Alka " Discer and Capper	BF 30
Clarke Built Ltd., Power Road, Chiswick, London, W.4	EG and EGV and " Gravac " Auto Fillers and Discers	BF 23, 32
Clares Ltd., Wells, Somerset	Discs and Discers (Hand)	
Geo. S. Clayton Ltd., St. Anne Street, Limehouse, London, E. 14	Auto Fillers and Discers	
Crown Cork Co. Ltd., Southall, Middlx.	Crown Corks	BF 28
Dawson Bros. Ltd., Ventnor Works, Gomersal, Leeds	" Hydrofilcap " Combined Washer, Filler and Discer	*See* Fillers
Dairy Supply Co. Ltd., Cumberland Avenue, Park Royal, London, N.W.10	Discs, Aluminium Caps, Discers	BF 21, 29
Graham Enock Mfg. Co. Ltd., Windus Road, London, N. 16	Auto Filler, Discer and Capper	*See* Fillers
Crown Cork Co. Ltd., Hayes, Middlesex	Crown Corks and Crowner	*See* Fillers
Hans Hanover Co., Soborg, Copenhagen	" Titan " Fully Auto Filler and Capper	*See* Fillers
U.D.E.C., Ltd., Cumberland Road, Park Royal, London, N.W. 10	Fully Auto Filler and Capper	*See* Fillers
Fords (Finsbury) Ltd., Kitcat Terrace, Bow, London	Auto. Aluminium Capper " Kovercap " Bottle Seal	BF 25
Smith Bros. Co. Ltd., 110 Pratt Street, London, N.W. 1	Sealcaps, Discer	BF 24
Waxed Papers Ltd., Watford, Middx.	Tabbed Discs	BF 20
Perkins Ltd., Mansfield Road, Derby	Cappers and Fillers	
R. W. Webster & Co. Ltd., Abbey Iron Works, Waltham Cross, Herts.	Crown Corking Machine	BF 27
Vipan & Headley, Leicester	Discers	BF 22

It is fitting to remember here that in general aluminium caps are supplied in self colour, though in almost all cases each dairy has its name or design die stamped on the caps whether these be pre-formed or made on the machine itself.

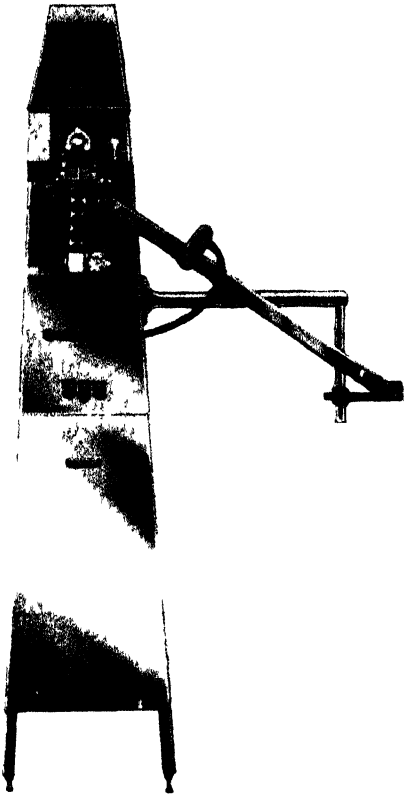


FIG. BF 34.—*Fords Synchro-strip Capper*

[*Photos by courtesy of Fords Ltd*

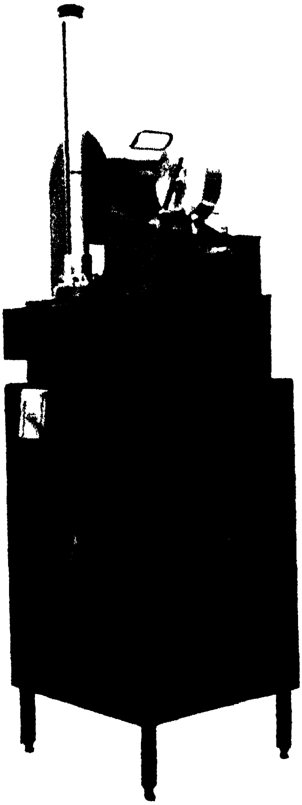
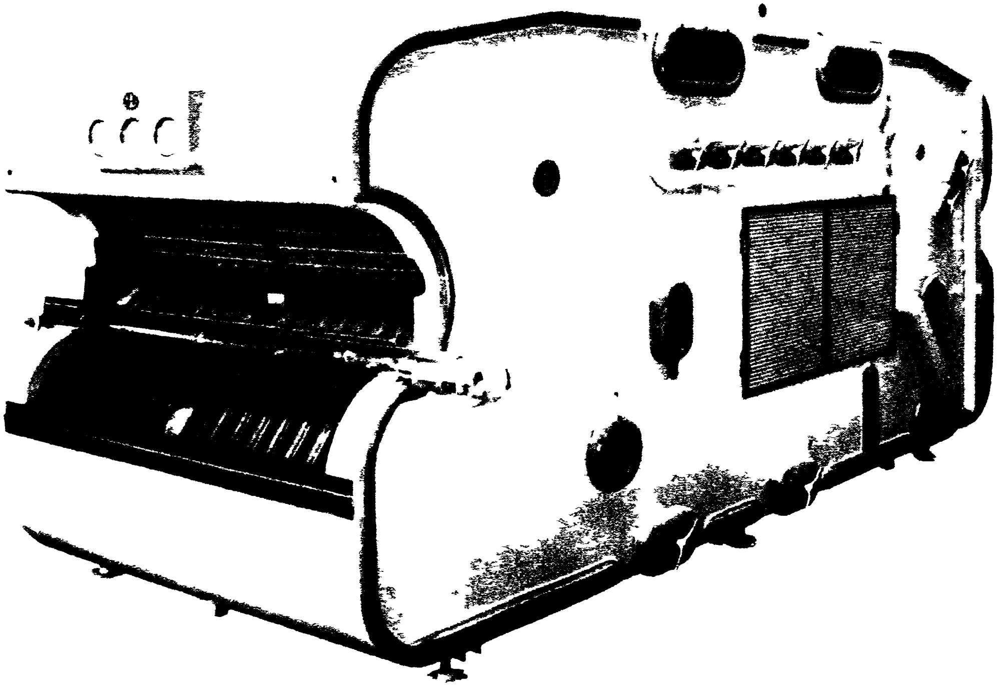


FIG. BF 35.—*Fords Stacking Press.*



[By courtesy of the Graham Enock Mfg Co Ltd

FIG BW 3A —JM 4 Gem Fluid Drive Soaker Sprayer Bottle washing Machine of the ' come-back " Type

At a slight extra cost, coloured lacquered strip can be supplied which adds a touch of individuality or advertising value to the bottle. It serves also, where a number of colours are available, to identify any one day's issue of bottled milk and so gives a degree of protection to the dairy against bogus claims. Carrying this development further it is now possible to have pre-formed caps or pre-printed foil for use on the dairyman's own automatic capper decorated in multi-colours and so arranged that the completed cap is applied on the bottle with the design registering accurately.

The next stage is the application of the cap. This is done by the capper in a manner similar to the fitting of the bottle disc. In most cappers the rising bottle table lifts the bottle into the closing head where a rubber ring is closed in on the edge of the cap forcing it into the special groove at the bottle mouth, so completing the operation. In another machine, Fig. BF 8, the capping head comes down on the bottle. The final effect is the same.

Many of the combined fillers and cappers are so made that the capping heads fitted for discing can be exchanged for heads applying aluminium caps.

A recent type of filler is illustrated in Fig. BF 16. *See* Bottles; Costings, p. 314 ; Retail.

BOTTLES, MECHANICAL STRENGTH AND THERMAL SHOCK TESTS. *Ref.: LCDP.*

BOTTLES : TESTS FOR STERILITY. The old Milk and Dairies Order required bottles to be washed as soon as possible after use, and cleansed and scalded with boiling water or steam before they were used again. Very few dairymen carried out these regulations, but in practice the modern bottle-washing machine with its hot detergent treatment delivers an almost sterile bottle if properly managed.

The Milk and Dairies Regulations (1949) (S.I. No. 1588) require that a milk vessel " shall as soon after use as is practicable be thoroughly rinsed and washed with or without detergents and, before it is used again, shall be scalded with boiling water or steam or otherwise effectively cleansed with an oxidising or preservative agent. . . ."

Various techniques and standards for " sterility " have been suggested. The U.S.A. Public Health Service Milk Ordinance and Code (1935) requires a standard of 1 colony per ml. capacity. Mattick and Hoy in 1937 suggested the more severe standard of 200 per bottle, and in 1939 the American Public Health Association recommended a standard of not more than 1000 colonies for a quart, 500 for a pint and 250 for a half pint bottle.

Hobbs and Wilson (1943), *JH*, 43, 106, suggest a limit of 600 for pint bottles, with corresponding values of 1200, 300 and 200 for quarts, half and third pint sizes.

In 1947 the Ministry of Agriculture (National Milk Testing and Advisory Scheme) suggested a standard of 200 colonies per bottle. In view of the widespread use of this technique it is given below in full. (B 743/T.P.B.)

Rinse Method for the Examination of Washed Milk Bottles (Provisional Technique). The method outlined is designed to give information on the condition of bottles immediately after washing. The number of bottles examined at each test is left to the discretion of the worker concerned but it is suggested that at least four selected at random should be tested.[1]

(1) ***Age of bottles at examination.*** Bottles for examination shall be selected immediately after washing, closed with a sterile rubber bung,[2] and examine

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[1] When a machine is giving occasional unsatisfactory results it may be necessary to test a complete row of bottles.

[2] The rubber bungs shall be wrapped in greaseproof paper and sterilised in the autoclave for 20 min. at 15 lb. pressure. After closing the bottle with the bung, the greaseproof paper shall be used as a cover over the bung and neck of the bottle, being held in position by a rubber band.

within 4 hr. When the examination cannot be carried out within this period, the bottles shall be kept on ice or in a refrigerator at 35° to 40° F. and tested not later than 10 a.m. on the following day.

(2) ***Rinsing.*** 20 ml. of sterile ¼ strength Ringer's solution shall be added to the bottle and the bung replaced.[1] The bottle shall then be held horizontally in the hands and rotated gently twelve times in one direction so that the whole of the internal surface is thoroughly wetted. Allow the bottle to stand for not less than 15 and not more than 30 min. and again gently rotate twelve times so that the whole of the internal surface is thoroughly wetted.

(3) ***Testing.*** Immediately prepare 5 ml. plates in duplicate using Yeastrel milk agar and incubate at 37° C. for 48 hr. before counting.[2] The methods described in Memo. 139/Foods (Jan. 1937) shall be followed in preparing media, pouring, and counting of plates.

(4) ***Recording results.*** The results shall be recorded as the colony count per bottle. (The sum of the counts on the two plates multiplied by 2.)

(5) ***Interpretation of results.***

Colony count per bottle	*Classification*
Not more than 200	Satisfactory (S)
Over 200 to 600	Fairly satisfactory (FS)
Over 600	Unsatisfactory (US)

Explanatory Notes on Suggested Method. (1) The ideal in bottle washing is to obtain a clean sterile bottle, but this is not always practicable under ordinary working conditions, and it is found by experience that even bottles washed under what are almost ideal conditions may contain a few organisms.

It is necessary therefore to suggest a standard method for the bacteriological examination of bottles which will give an indication of the number of bacteria left in them and to propose a limit to the number that should be found by the suggested method, the assumption being that where that number is exceeded, the washing process cannot be regarded as satisfactory.

The method outlined is therefore designed to give information on the condition of bottles immediately after washing and not necessarily their condition just before being filled with milk.

(2) The number of bottles examined is important and will depend to some extent on the size and type of machine. The number suggested should be regarded as a minimum and a larger number taken whenever possible.

(3) Bottles should be examined as soon after sampling as possible as in the majority of cases they are used immediately after washing. This is particularly important where hypochlorites are used in the final rinse. In fact it might be advocated that they should be rinsed at once and the rinse taken back to the laboratory for examination. The objection to this procedure is that laboratory facilities for making such rinsings are not always available at dairies.

(4) The volume of rinse to be used has been fixed at 20 ml. for all sizes of bottle. The technique is intended to assess the efficiency of the washing process and bottles of all sizes should give equally satisfactory results if properly washed.

For ease and speed of working in some laboratories, 18 ml. of ¼ strength Ringer's solution are used, *i.e.* two tubes of 9 ml. each but this quantity tends to complicate the final calculation. Further, as it may be necessary to make up Ringer's solution containing thiosulphate sometimes, it was decided to fix the volume used at 20 ml.

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[1] 20 ml. of ¼ strength Ringer's solution shall be used irrespective of the size of the bottle. Where bottles are taken from a hot section of a machine for special purposes, they shall be fitted with a bung and allowed to cool before rinsing. Where the final rinse water is known to be chlorinated, crystalline sodium thiosulphate shall be added to the Ringer solution before autoclaving to give a concentration of 0·05 per cent.

[2] Additional information may be obtained by incubating plates at 22° C. and by testing for the presence of coliform organisms and for milk souring organisms.

(5) In making the rinse, the procedure of gentle rotation in the hands a definite number of times has been said to give better reproduction by various workers than shaking so many times. After complete wetting of the interior surface, a period of soaking is given and the process of rotation repeated. The method is that recommended by Hobbs and Wilson and is reputed to give reproducible results.

(6) The quantity of rinse suggested for each plate is 5 ml. This will give a plate count of 50 for a bottle count of 200, and a maximum plate count of 300 is equivalent to a bottle count of 1200. The range is wide enough and the plate count with 5 ml. will be more accurate than one of 1 ml. for the same bottle count.

Duplicate plates are suggested for greater accuracy with the better washed bottles. Incubation at 37° C. in preference to say 22° C. or 30° C. is recommended because the majority of laboratories are equipped with 37° C. incubators. Yeastrel milk agar is used as it is an official medium and in general use in most laboratories. A reference to additional tests is made in the notes at the end of the technique.

(7) The standard of a colony count per bottle of 200 may be considered by many to be somewhat stringent, but experience has shown that it can be attained easily where washing methods, whether carried out by hand or machine, are satisfactory. It should be emphasised that the standards refer only to bottles taken immediately after washing and examined within the period set down, and not to bottles just before being filled. Records of the conditions of operation of the machine at the time the bottles are taken for examination are essential for a proper interpretation of the results.

(8) No mention has been made of the question of wetness of bottles but if they are washed properly and sufficient time allowed for drainage little moisture should be left in them. Obviously the presence of excessive moisture is undesirable and calls for attention on the part of the management.

Refs.: LCDP; Griffiths *et al.* (1952), *SAB*, **15**, 126; Resuggan *et al.* (1953) *LP*, **2**, 534 (closures); Pritchard *et al.* (1953), *LP*, **2**, 353 (roll tube).

BOTTLE WASHING. One of the most important sections of dairy hygiene is the efficient washing and sterilising of the milk bottles. No matter what precautions are taken with the milk, or how thorough pasteurising may be, all this work will be nullified if the bottles are not in a bacteriologically satisfactory condition. The milk may be in the bottles for many hours, and during this time any infection in the bottle will have time seriously to affect the milk both from the standpoint of disease and keeping quality.

Returned milk bottles vary very considerably in their condition. There are those which are rinsed immediately they have been emptied, those which are not so treated, and bottles like school " thirds ", which have considerable and varying amounts of milk left in them, which may be soured or dried in the bottle, so that cleaning becomes much more difficult. Any considerable amount of deposit in a bottle will present a much more serious problem in summer than in winter.

Bottles vary in shape and size, the customary sizes being quarts, pints, half-pints, and one-third pints. In shape they vary from the customary non-shoulder type with wide mouths to the shouldered type with a narrow neck as in sterilised milk bottles, and recently square bottles have been taken up by some dairies. These differences also have a bearing on the problem of cleaning.

Principles of Bottle Washing. The principles upon which modern bottle-washing practice is based are few and simple. Firstly, the bottle must be freed from any large quantity of loose deposit or debris, otherwise the detergent solution will rapidly become foul. Secondly, the bottle must be subjected to treatment with a detergent capable of penetrating, removing, and emulsifying the remaining fat and milk film inside the bottle, and thirdly, the detergent should have the ability to destroy bacteria in the solution within a reasonable time. A considerable amount of work has been done on the destruction of bacteria by solutions of caustic soda, and as a result it is generally accepted that a high degree of caustic alkalinity in the solution is essential. Below is reproduced a table which shows the time, temperature, and concentration relationship for the destruction of 25 per cent. spores of *B. subtilis* by caustic soda (Hobbs and Wilson (1943), *JH*, **43,** 106).

Temperature	*Minutes*				
F.	1	2	4	8	16
120	2·44 %	1·64 %	1·10 %	0·74 %	0·50 %
130	2·15 ,,	1·44 ,,	0·97 ,,	0·65 ,,	0·44 ,,
140	1·90 ,,	1·28 ,,	0·86 ,,	0·58 ,	0·39 ,,
150	1·66 ,,	1·12 ,,	0·75 ,,	0·51 ,,	0·34 ,,
160	1·46 ,,	0·98 ,,	0·66 ,,	0·45 ,,	0·30 ,,

Although caustic soda has been the main test material in bottle-washing research from the bacteriological point of view, some American workers have gone further and examined the effect of other substances upon the killing power of caustic soda. They found that the addition of certain other alkaline salts, notably sodium carbonate, enhanced the killing power of caustic soda, and this would appear to be in line with practical observations made by other people.

The surface tension of the solutions is now also recognised to be an important factor in the killing power of alkalis, and the reduction of the surface tension to between 40 and 30 dynes per cm. increases the killing power of an alkaline solution several times. In devising modern detergents all these facts are taken into consideration. Again, it is possible to use some features in some machines just as it is necessary to exclude others.

The next step is the rinsing of the bottle free from all traces of detergent and the production of a visually clean and bacteriologically satisfactory final bottle. This is usually done by following the detergent treatment with a warm rinse and following this by a cold mains rinse, which leaves the bottle in a condition finally satisfactory and ready for filling. This cycle of operations is universally accepted and all machines operate upon it, but variations occur in the length of time for each operation, and the mode in which it is carried out. The question of the detergent temperature, which naturally should be as high as possible, is conditioned by the length of time which may be spent in raising the bottle to the maximum detergent temperature, and it is further conditioned by the extent to which the machine manufacturer is willing to provide intermediary soaks or rinses, which will have the desired effect of conditioning the bottle to the required temperature change. Here, obviously, there must be economic and practical limitations. In practice it is possible to raise the temperature of a milk bottle from 35° to 140° F. in from 2 to 3 min., but it is important that the bottle should receive the increased temperature *outside* and not inside, that is to say, it should receive a warm outside flushing, and any inside rinsing should be at a temperature rather lower than the outside. At the other side of the detergent tank the bottle must be conditioned to lower temperatures before taking the final rinse, and here the quickest cooling is achieved most safely by applying an *internal* rinsing, the temperature of which is lower than any outside washing the bottle may be getting. The quality of the glass in the bottle will also be an important factor and bottles can be produced which are highly resistant to thermal shock, but will, of course, be more expensive than the ordinary milk bottle.

It is important that the detergent should have good rinsing properties, a point which is discussed in a separate section on Detergents (*see* p. 367). This will ensure that the detergent is quickly removed from the bottle and, with it, any traces of remaining bacteria. The strength of solution to be used in the detergency operation may vary from ¾ per cent. to as much as 3 per cent., and this will depend upon the detergent being used and the machine in which the detergent is being used. As a general rule, the strength of detergent in a soaking tank must be stronger than that being used for "jetting" work, and this will be obvious since a good deal of the work in a hydro-machine is done by the physical action of the pressure jet. In the "soaker" the removal of milk residues from the bottle will depend much more upon the chemical and physical characteristics of the solution itself, and here such factors as low surface tension will be found to confer great benefits. It is true, also, to say that the bottle must spend a much longer time in soaking than it would under the hydro jet; hence, in order to provide a given output of bottles a soaker machine must necessarily be larger, or at any rate, have a greater cubic capacity than a "hydro". On the other hand, it must be borne in mind that the efficiency of the hydro-machine depends upon the jets working satisfactorily, and the blocking of jets in a hydro-machine can speedily reduce its efficiency very seriously indeed. It is just another instance of the way in which the old "soaker versus hydro" argument can be shown to be futile, because both systems have much to be said for them. Again, in the purely soaking type of machine, it can be claimed that there are no pumps to give trouble although, in point of fact, most soakers to-day do incorporate a little jetting somewhere, and so become "soaker-hydros".

Methods of Washing and Types of Machine. (1) ***Handwashing.*** There are roughly five methods used in bottle cleaning. In the simple handwashing method, now almost extinct, the bottles are brushed in a weak solution of detergent at a temperature not too uncomfortable for handling, and then rinsed in a tank into which fresh water continually flows. This is a method really only met with in very out-of-the-way small country dairies, and it is safe to say that very few dairies now use this very simple method. Obviously, such a method cannot be expected to give very good results, firstly, the detergent is weak, and only mildly alkaline, and at the temperature used cannot be expected to be able to kill the bacteria. Next, the brushes, unless very carefully sterilised each day, will become highly contaminated, and usually the final rinsing is insufficient to ensure the complete removal of bacteria which may be left from the previous stage.

(2) ***Non-automatic soaking systems.*** The next method, which is widely used, consists of a hand-operated soaking machine. In the best types of soaking tank in this case, the bottles are placed in a long crate which is hinged to the soaking wheel in such a way that the bottles are immersed in the soaking tank in a vertical position so that the detergent solution completely fills the bottle, and the loose material and debris tend to flood to the top and thus escape into the bulk of the solution. The temperatures that can be used in this case are also reasonably high, usually about 120° to 130° F. and it is possible also to use strongly alkaline detergents, although when unloading a crate after soaking, the operators will have to use rubber gloves to avoid injurious burns. The bottles thus removed are rolled down an incline into a rinsing trough where they receive a water rinse, usually at a temperature of 90° or 100° F. From this trough they are removed and given an internal and external brushing by means of revolving brushes, while the partial immersion of the bottles in a horizontal position in water, which is continually refreshed, ensures satisfactory condition before the bottles are placed on to the final rinsing wheel, where they receive a fresh mains water final rinse. Various modifications of this system are in use.

Automatic Machines. (3) ***Soakers.*** Automatic machines, which are by far the greatest in number in modern dairies, consist of three main types: soaker,

soaker-hydro, and hydro. Considerable discussion has centred around the merits of these three types, but in fact, all of them, when properly operated, give satisfactory results. By " properly operated " we mean operated at the temperatures and pressure specified by the manufacturers, and using the correct detergent for the water supply and local conditions which obtain, *e.g.* speed of return of bottles, availability of water supplies, age and condition of machine, and type of labour.

One of the most important features of all three types is the pre-rinsing section. It is here that the bulk of waste milk and deposits should be removed. Machines may either be loaded and discharged at the same end, or else loaded at one end and discharged at the other. The first of these is called the " come back " type, and the second, the " straight through " type. A consideration here is that in the " come back " type the carriers are utilised during the whole of their run through the machine, whereas with the " straight through " type the carriers are only in use half the time of the total run through the machine, that is, they are returned from the discharged end to the loading end without carrying in bottles. This immediately brings up the question of space and of operators. But, whereas, on a small machine of the " come back " variety, an operator can both load and inspect the discharge, on a large " come back " type it is necessary to have two men loading and, of course, watching the discharge, so that for the larger types there is not much to choose between this and the " straight through " variety. It is quite evident that the dairyman must consider a number of factors before selecting any particular machine, and these factors vary so considerably from dairy to dairy that it is safe to say that there are at least two makes of machine which suit any particular dairyman's requirements.

Size and shape are very important, and in times such as these, when building is difficult or impossible, the satisfactory utilisation of every square foot of space in the dairy makes the question of size and shape a matter of primary consideration. In the soaking type of machine a pre-rinsing tank at a low temperature is followed by one, or more, successive soaks in detergent tanks where the temperature reaches its maximum. The bottles are loaded into conveyors which are carried up, over, and down into the first tank through the lower regions of the tank and then up and over again into the second tank, and so on throughout the machine. The maximum temperature reached is often 150 in such soaking systems, and after leaving the hot detergent tank the bottle is subjected to soaking rinses of progressively lower temperature until it is finally discharged in a cool condition. In some cases a final steaming of the bottle is arranged, and in this case the system may finally climb in temperature to 180° before the bottle receives its final steaming, but it is safe to say that this arrangement has almost passed out of use.

(4) ***Soaker-hydro types.*** The soaker-hydro type still uses the soaking tank for the maximum detergency effort, but incorporates very often a jetting pre-rinse in which warm water is pumped through jets into the bottles releasing adhering residues, so that the bottle passes forward to the detergent soaking tank in a fairly reasonable condition. Following the detergent soak there is usually a detergent jetting arrangement whereby some of the detergent solution is pumped from the soaking tank into the bottles as a final detergent rinse before the bottle passes over to the rinsing section. Here the bottle usually receives a jetting warm rinse, and this, in turn, is followed by a cooler rinse and finally by a cold mains rinse. Brushes are sometimes incorporated into these soaker-hydros, but for dairy work these have practically disappeared, the reason being that the residues in milk are far more dangerous from the point of contaminating the brushes than are the residues obtained from beer or mineral waters, in which trades bottle washing is also of importance. Once again, variations of the number of tanks, sequence of rinses, and general layout occur within this class, while many manufacturers are quite ready to make any modification in the design

of the machine to suit the desires of the particular purchaser. In one kind of soaker-hydro of the " come back " type the bottles are given a pre-rinse jetting, and then transferred into the main tank, and they proceed downwards along the bottom of the tank in a vertical position with the mouths of the bottles upwards. In this way they pass along the whole length of the machine in detergent solution, passing over the wheel at the end and thus being carried upwards and out of the solution so that they drain thoroughly and over into another detergent tank where passing round a wheel, they receive a second soak. As the bottles enter this tank they are on their way back through the machine. Upon leaving it they proceed in an inverted position over a series of detergent spray jets; the detergent for these jets is supplied by a separate detergent tank, and this means that this detergent solution will remain in a clean condition for a very long time, because the bottles will be in a fairly clean condition after their prolonged soaking. The bottles continue on their way and are then sprayed by warm water, or by hot water, followed by either a hot mains rinse or a cold mains rinse, depending upon whether the bottles are to receive a final steaming, or not. Diagrammatic representation of this type of soaker-hydro is reproduced in Fig. BW 1.

On this type of machine it is customary to change the spray tank detergent more frequently than the soaking tank detergent, thus ensuring that the spray tank detergent is practically always clean, and this certainly means that risk of contamination of the hot rinse tank is very slight, and this must be considered a satisfactory feature. In all bottle-washing machines which have a warm rinse water tank there is the danger of the re-infection of the bottles because of the bacterial growth in this rinse water. Carry-over in many machines of the ordinary detergent solution is inevitable, and if this happens to be anything but clean, bacteria will begin to multiply in the rinse tank, and as the temperature here is often ideal for growth, the danger of contamination is great: although the bottles may be shining bright and physically clean they will carry a degree of contamination which may endanger the keeping quality of the milk, and the health of the consumers. On this point it may be as well to mention that a sparkling bottle from a machine is no guarantee at all of its bacteriological condition. While the agreeable appearance of a sparkling bottle will always remain a desirable feature in any dairyman's eyes, the final arbiter of the success, or otherwise, of the bottle-washing system is the bacteriologist.

Another make of soaker-hydro employs a soaking pre-rinsing tank of weak detergent solution, the bottles being taken through the pre-rinse tank in carriers, the connecting chain of which passes over wheels and then transfers the bottles to the detergent soak tank which operates at a temperature of 145° F. After this the bottles receive a detergent jetting from the solution in the soaking tank, and then receive an external sluicing with weak detergent solution at about 95° F., followed by a similar flushing at 80° F. The bottles then receive an internal jetting and external flushing with re-circulated water, the temperature for this being 65° F. Finally, the bottles receive an internal mains water jetting and an external mains water flushing. A feature of this machine is the fact that it is operated by a hydraulic engine, and this permits any variation in speed between the upper and lower speed limits, so that the machine can always be adjusted exactly to the requirements of the rest of the milk plant. This arrangement also minimises the risk of damage in the event of any breakages bringing the machine to a standstill. Lubrication difficulties, where these exist, are also shown up by the pressure gauge on the hydraulic engine, and where an unsuitable detergent with poor lubricating qualities is being used it is possible to see the effect at once. A diagram of this kind of soaker-hydro is reproduced in Fig. BW 2.

Yet another type of soaker-hydro designed to handle the smaller outputs is constructed on the " come back " principle, and in its construction has evidently been designed to give the maximum economy in space. Its particular features are a soaking pre-rinse, followed by a detergent soaking at 145° F. This is

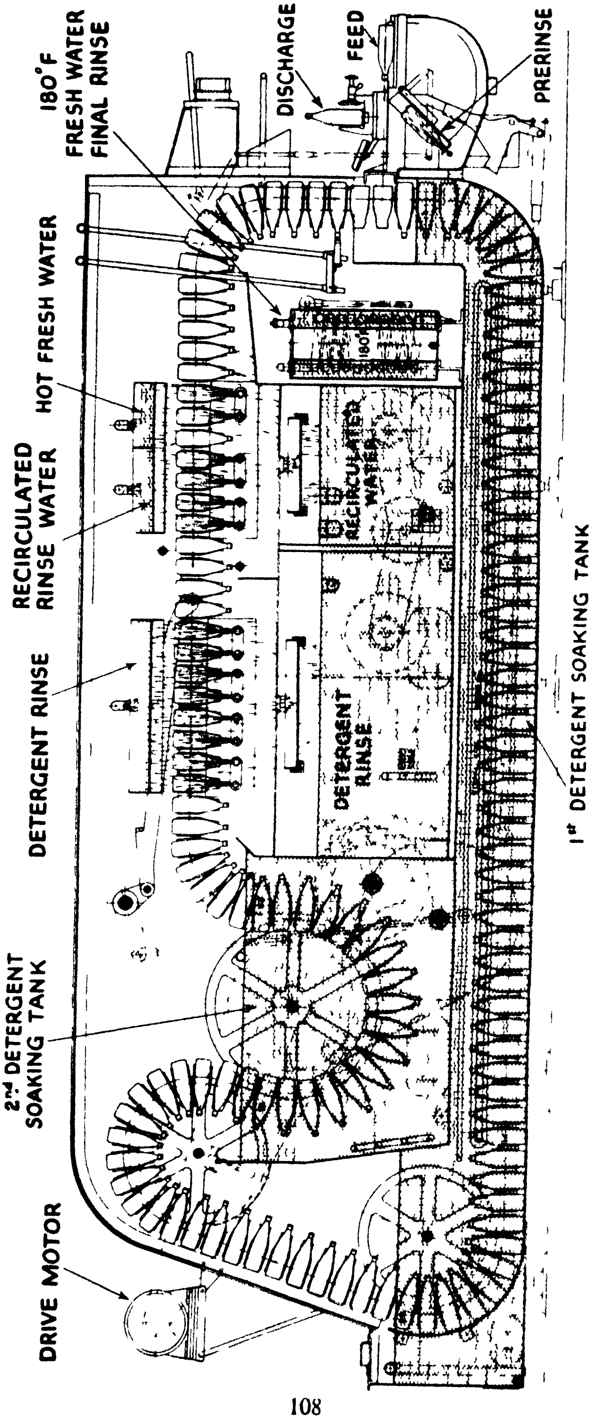
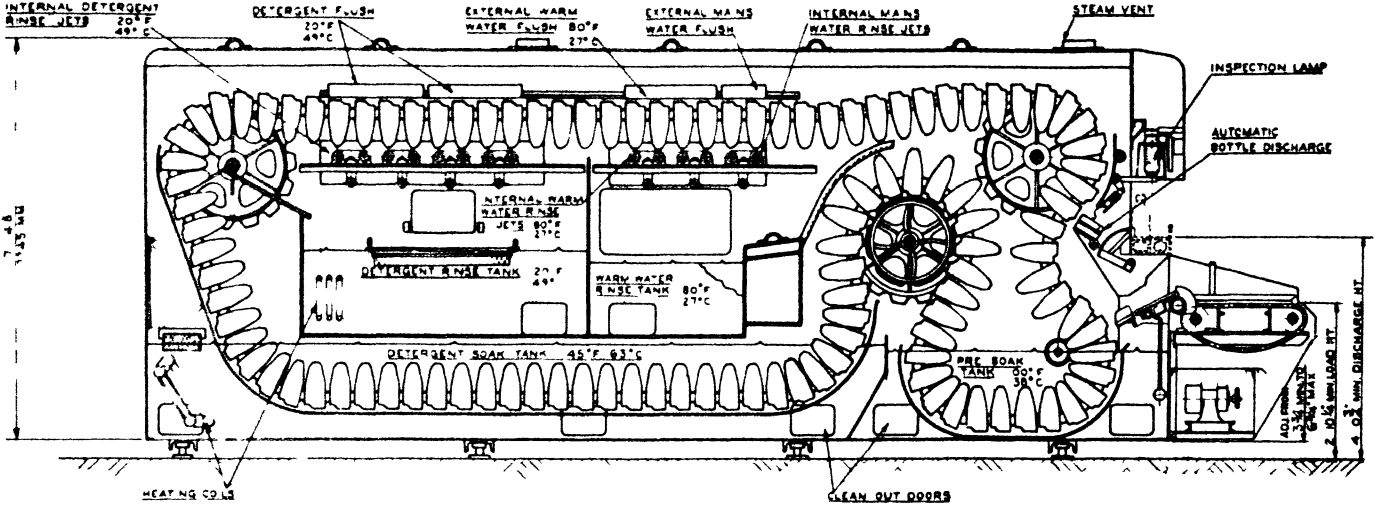


FIG. BW 1.—*Bottle-Washing Machine*

[*By courtesy of R. W. Webster & Co., Ltd.*


INTERNAL DETERGENT RINSE JETS 20° F 49° C
DETERGENT FLUSH 20° F 49° C
EXTERNAL WARM WATER FLUSH 80° F 27° C
EXTERNAL MAINS WATER FLUSH
INTERNAL MAINS WATER RINSE JETS
STEAM VENT
INSPECTION LAMP
AUTOMATIC BOTTLE DISCHARGE
INTERNAL WARM WATER RINSE JETS 80° F 27° C
DETERGENT RINSE TANK 20° F 49°
WARM WATER RINSE TANK 80° F 27° C
DETERGENT SOAK TANK 45° F 63° C
PRE SOAK TANK 90° F 38° C
3' 3¾" MIN TO 6' 6¼" MAX
2' 10¼" MIN LOAD HT
4' 0¾" MIN DISCHARGE HT
HEATING COILS
CLEAN OUT DOORS

[By courtesy of U D Engineering Co, Ltd

FIG BW 2 – *Bottle-washing Machine*

followed by a warm rinse at 80° F. and, of course, the final mains rinse. This type of machine handles up to 6000 bottles per hour and a sectional diagram of its operation is reproduced in Fig. BW 3.

A recent type of soaker-hydro is illustrated in Figs. BW 3*a*, 3*b* and 3*c*.

(5) ***Hydro types.*** The next class of bottle-washing machine to be considered is the hydro. In this type there are no soaking tanks whatsoever, and the sequence usually consists of a jetting pre-rinse which raises the temperature of the bottle at the same time, thus preparing it for the hot detergent solution which immediately follows the pre-rinse. The temperature of the detergent is usually between 130° and 140° F. and afterwards the carriers take the bottles along to the warm rinse section, and finally they are passed to the cold mains rinse. Again, many modifications of this system have been produced, machines with more than one detergent tank are frequently met with, and the second detergent tank in such machines often has a temperature of 150° or 160° F., a very satisfactory temperature from the point of view of sterility. Here again, the rinse sections must also be doubled in order to provide the gradual stepping down necessary if the breaking of bottles from thermal shock is to be avoided, so that it will be seen that for the more elaborate arrangements larger machines must be built (Fig. BW 4).

The main principle of this class of machine is pressure-jetting operated by means of a centrifugal pump. The principal varieties in hydro-washing machines are (i) chain type, (ii) wheel pattern, and (iii) tunnel washers, the latter being an early variety which has now almost passed out of use. Jetting pressures range from 12 to 20 lb. per sq. in. and occasionally even higher; in fact, the tendency in recent years has been to step up the pump pressures. It is rather doubtful whether increasing the pump pressure beyond 15 or 16 lb. per sq. in. really achieves much better cleaning, while, on the other hand, even the slightest tendency to foaming will be considerably multiplied as the pressure goes up. The problem of the higher pressures is bound up with the speed of operation of the machine and the urge to obtain the maximum " through put " for a minimum size of bottle washer. Excessive foaming is one of the curses of the modern high pressure bottle-washing hydro, and a great many factors come into play. The finish of the jets, for example, would appear to have an important bearing on the problem, while in the interval between the passing of two bottles over the jet, the spraying of the jet and the striking of surfaces when the jet is not playing in the bottle, will make for aeration of the detergent solution with a greater degree of foam resulting. It is not fair, however, to blame excessive foaming altogether on to the modern high pressure machines. Detergents, too, have made considerable strides, and in achieving higher cleaning power the natural tendency of detergent solutions to foam may have been increased. In the chain type machine the necessary cups for holding the bottles are carried by endless chain over the tanks which supply the jets, both inside and outside, to the bottles. The fresh water warm rinse is usually continuously fed from the final mains rinse while this, in turn, is pumped back to form the pre-rinse. Even so, the warm rinse is still the main focal point of bacterial growth in the machine, and every effort should be made to keep this as near sterile as possible. That the water in this tank should be completely changed every day is obvious, and the addition of hypochlorite maintained at just a few parts per million during the run will effectively keep down the bacterial population. Fig. BW 4 is a sectional photograph of a typical chain type hydro bottle-washing machine which uses pre-rinse, detergent jetting, warm fresh jetting, and mains water final rinsing as its jetting sequence.

Another important chain type machine dispenses altogether with the warm rinse tank, and thus eliminates a possible source of re-infection of the bottles (Fig. BW 5). In this class of machine the sequence is warm pre-rinse, hot detergent jetting, warm mains water rinse, and finally the cold mains water rinse. Instead of a warm rinse tank, mains water is used, this being passed through

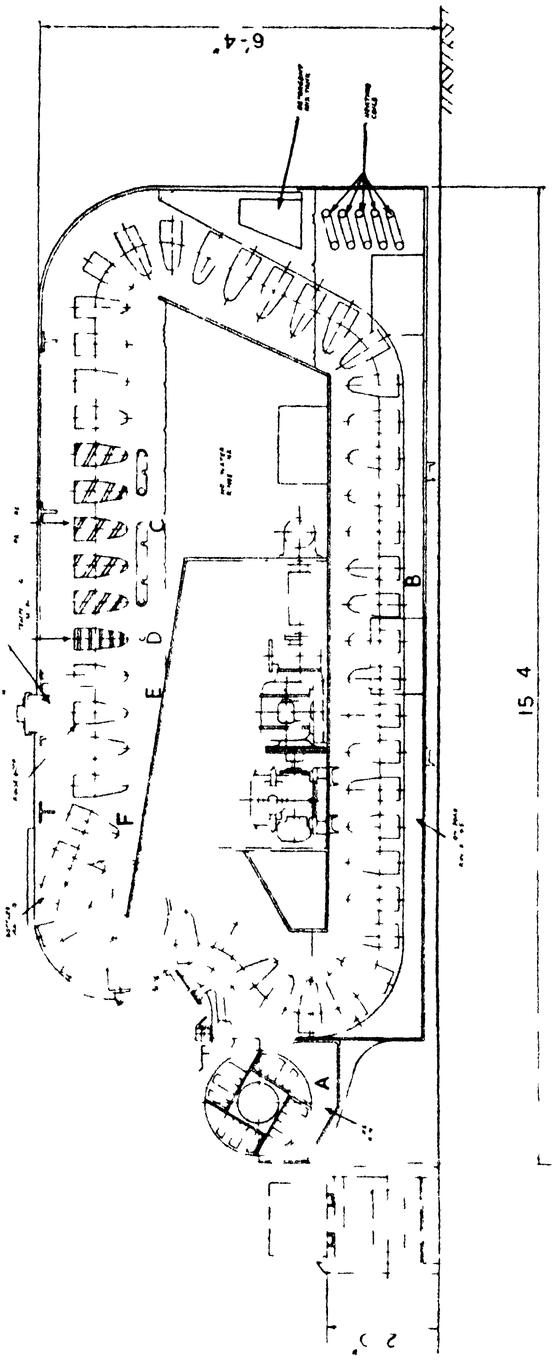


Fig. BW 3 —Bottle-washing Machine

[By courtesy of Graham Erock Mfg Co

a coil in the detergent tank and thus warmed to a suitable temperature. This water is afterwards utilised for the purpose of pre-rinsing.

In all hydro machines it is very important that the bottles should be centred accurately over the jets.

An important point in bottle washing is to give the bottle an adequate period of draining between each section of the machine. In other words, between pre-rinsing and detergent jetting, between detergent jetting and warm rinse jetting, and between warm rinse and final jetting it is advisable for a suitable draining period to be arranged. This will definitely mean economy in detergency by avoiding excessive carryover, and where warm rinse tanks are involved will result in their being kept in a much better bacteriological condition, and there is a tendency for modern machine manufacturers to pay attention to this quite important point (Fig. BW 6). Quite obviously, the provision of adequate drainage space also means that the size of the machine will be increased, and here again it is a question of balance ; the space and size of the machine being considered with the efficient arrangement of the bottle-washing process. There have been in various trade journals from time to time discussions on the question of the ideal bottle-washing machine, but it is now generally realised that it is almost impossible to design a bottle-washing machine which, no matter how ideal theoretically, will be ideal in the practical sense that every dairyman will find it admirably suited to his needs. The question of lubrication of bottle-washing machines is also one of considerable importance, although it appears to be of greater moment for some makes than for others. Caustic soda has long been known for its excellent lubricating properties but, unfortunately, although it has strong powers of hydrolysis and bacteria destroying ability, in many other respects, its properties as a detergent show serious deficiencies, *e.g.* it rinses badly, etches glass ware, has poor wetting powers and does not prevent scale deposition. Consequently the compounded or balanced detergent has arisen and very largely superseded caustic soda as a bottle-washing detergent. This has meant the incorporation of other alkaline salts which do not promote lubrication in the same way that caustic soda does, and consequently difficulties of lubrication sometimes have to be considered. Here again, it is up to the detergent manufacturer to be sure that he can provide the proper detergent for the particular machine, and to avoid incorporating more than the maximum amount of non-lubricative salts for the requirements of the particular machine. Silicates have become an important part of the compounded detergent, but above a certain percentage of SiO_2 in the composition there will be a tendency for the deposition of a film of hydrated silica upon the metal surfaces which will increase resistance and friction several times. The author finds that this particular point can be demonstrated in a very striking way, as the result of an experiment carried out in his laboratory a year or two ago. A piece of mild steel was soaked in a solution which contained 2 per cent. of a silicate in which the $Na_2O : SiO_2$ ratio was 1 : 2. After this soaking, the metal was thoroughly rinsed in both hot and cold water and then passed to a phosphating bath in order to phosphatise the surface of the metal in the well-known way which is used for the prevention of corrosion. After half an hour's treatment in the standard phosphating bath, the mild steel was withdrawn and found to be absolutely unaffected by the treatment. Repeated attempts to bring about the required reaction in the bath all failed uniformly. But after rubbing the surface of the mild steel plate with a fine abrasive, immersion in the phosphating bath gave good results in under 10 min. This experiment clearly demonstrates the power of the silicates to form protective adsorbed layers on metal surfaces and, as is well-known, deposits of this type are highly friction-promoting. The result of throwing sand into machinery is an instance of a similar sort of effect, although on a much exaggerated scale. Just as an adsorbed silica film promotes friction, so do adsorbed films of other kinds have the reverse effect. For instance, many soaps and wetting agents form adsorbed films on

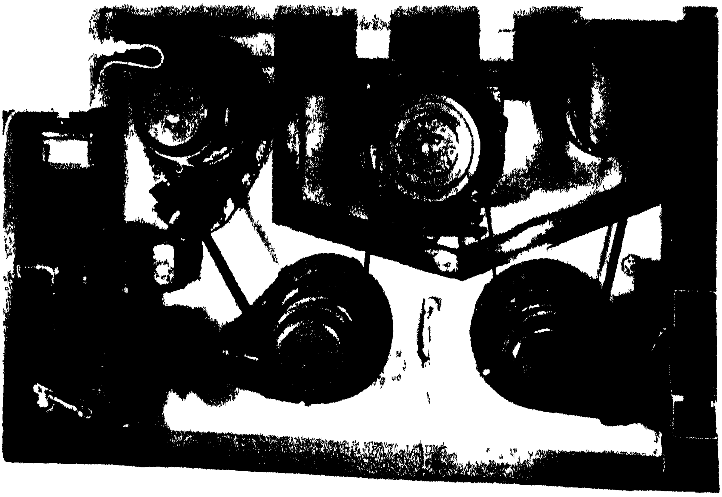


Fig. BW 3b *Pumps Driven by One Belt*

[*Photos by courtesy of Graham Enock Mfg. Co. Ltd.*

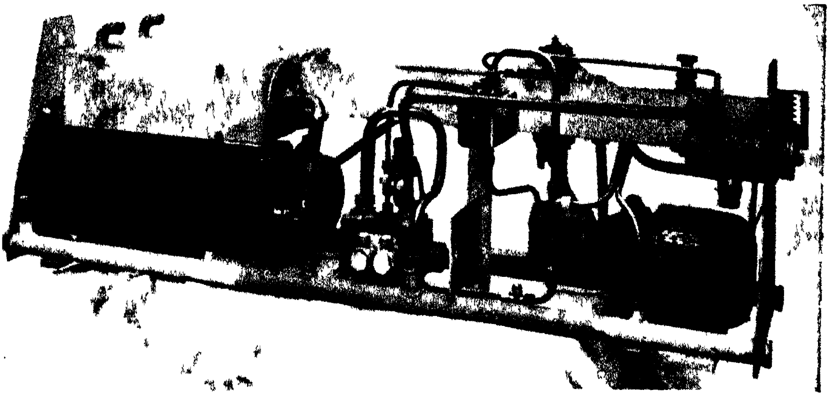
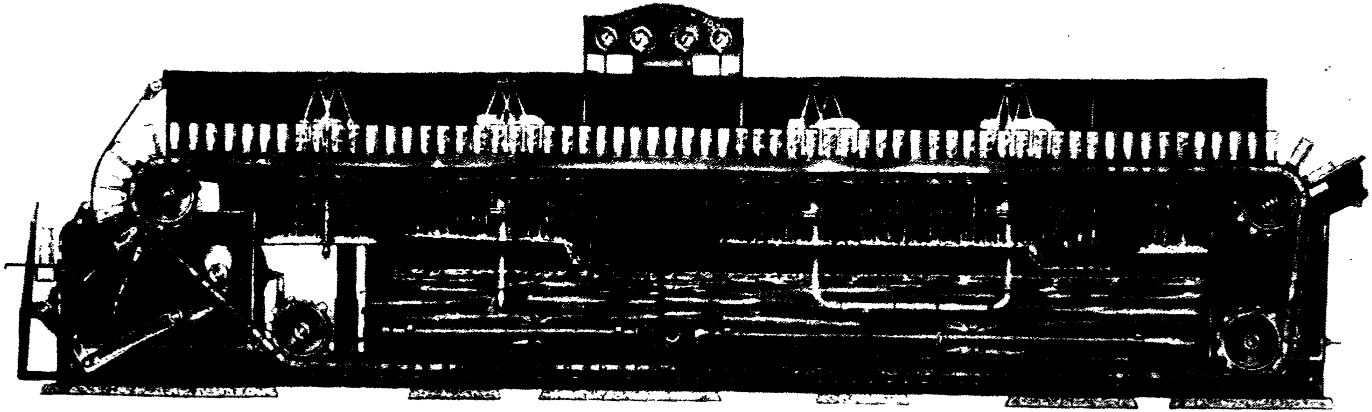
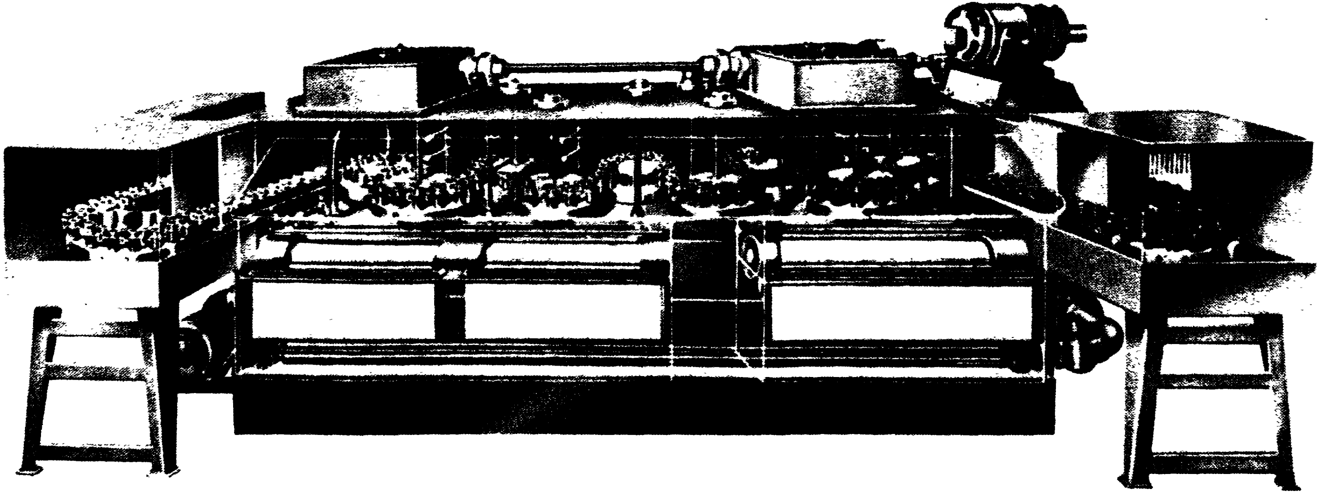


Fig. BW 3c *The Fluid-drive Generator is a Self-contained Unit*



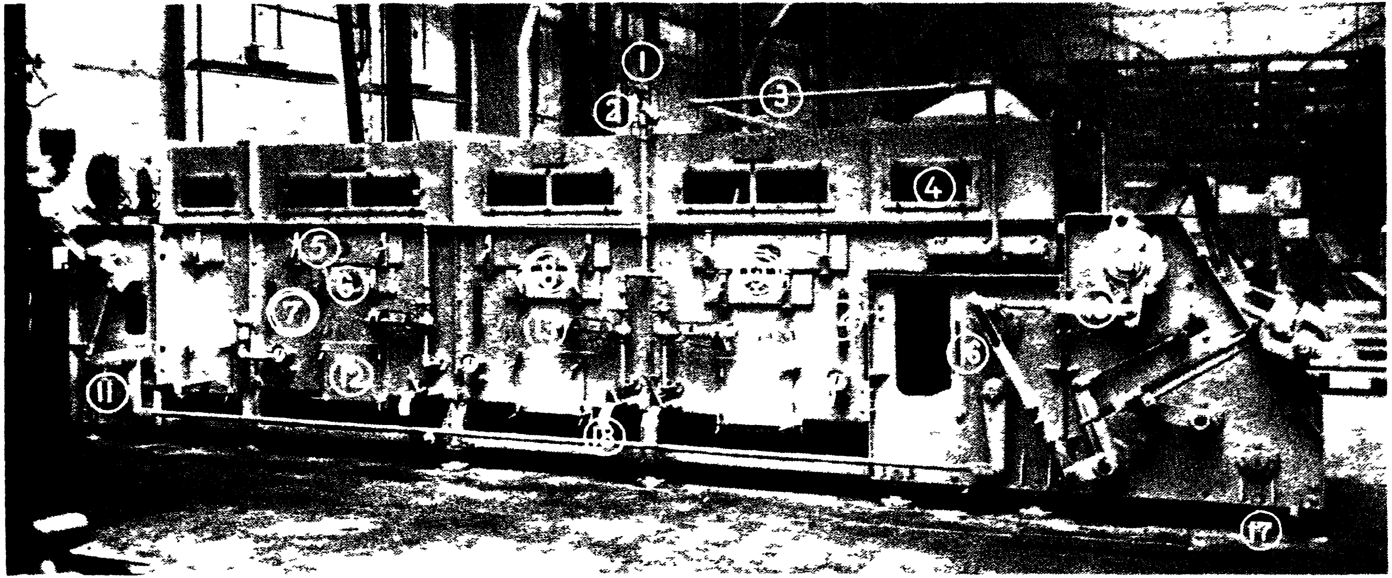
[*By courtesy of Dawson Bros. Ltd.*

FIG. BW 4.—*Sectional View of a Typical Hydro-washer incorporating a Warm Rinse Tank.*



[*By courtesy of British Miller Hydro Ltd.*

FIG. BW 5.—*Operational View of Non-rinse Tank Type of Hydro-washer.*



[By courtesy of Auto Dairy Engineers Ltd

FIG. BW 6.—" *A D E* " *Straight-on Washing Machine*

(1) *Steam supply to machine* (2) *Steam strainer* (3) *Water supply to final rinse from town water supply.* (4) *Inspection windows* (5) *Jet pipes* (6) *Portable strainers withdrawn* (7) *Detergent tank* (8) *Hot water tank* (9) *Attemperating tank* (10) *Ratchet and pawl drive mechanism* (11) *Chain adjustment* (12) *Sludge doors* (13) *Self-acting thermostats* (14) *Water level glasses* (15) *Thermometers.* (16) *Lubricating nipples* (17) *Adjustable feet* (18) *Quick opening drain cocks.*

metals which are shown to promote lubrication and reduce friction between the surfaces. Wetting agents may, therefore, be considered as useful in this respect, but even better are the cationic wetting agents of the quaternary ammonium type, because these are much more strongly adsorbed to the surface. Obviously, in any machine, sensitivity to lubrication will depend upon the total area of moving parts in contact with each other and exposed to contact with the detergent solution. Thus, machines in which the bottle carriers are attached to endless roller chains at either end usually show less sensitivity than other types. The hardness of the water also plays a part in lubrication because deposits of lime salts will produce a friction promoting surface, and hence it is important, as far as possible, to avoid the use of hard water if the detergent or water treatment is not capable of preventing deposits. On the other hand, it has been found that with most types of machine, the movement of surface upon surface is, itself, sufficient to keep the deposited hardness from forming any appreciable layer at the friction boundary, and practice shows that scaling up is not so much a cause of poor lubrication as are detergents which are not properly balanced with respect to the machine in which they are going to be used.

Heat. It is important for detergents in bottle washing to be used at a reasonably high temperature for reasons which are stated above, and also in the section on detergents. Consequently, the detergent tank, or tanks, and the rinse tank, or tanks, must be heated to the required temperature. This can be done by open steam pipe or closed coil steam pipes, as desired. For heating the detergent tank the closed coil system is almost invariably used, since open steam pipe would result in a rapid dilution of the solution. The heat from the detergent tank, or tanks, can also be utilised for warming adjacent rinse tanks, and each manufacturer has his own methods of economising in the use of steam. The temperature is often thermostatically controlled so that it does not fall below, or exceed the limits imposed by, the particular arrangement of tanks, or the design of the machine. The question of fuel economy makes it important that the surface of the steam coil shall be kept free from scale and deposit, while only too frequently fuel shortages in the post-war years have meant that tanks are running at temperatures below the safety limit for the destruction of micro-organisms. This is another reason why the detergent should be capable of keeping the machine as free from hard water scale as is possible. The deposition of slimy films on the steam pipes should also be avoided, as the power of such a stagnant film to resist heat transference to the solution is remarkable. As a general principle, therefore, it will be seen that the thorough cleaning of the detergent and other tanks at regular intervals, and the scouring, if possible, and thorough cleaning of the heating coils, is essential if proper economy and maximum efficiency is to be obtained from the heating system. Direct gas heating, or electrical heating, although theoretically possible, is not adopted in practice because of very obvious difficulties in the case of the former, and of expense in the case of the latter. Nevertheless, cases have been met where both these adaptations have been improvised, but it is not necessary to consider them owing to the fact that such arrangements are hardly ever met with.

Inspection and Cleaning Arrangements on Machines. It is most important that inspection of all sections of the cleaning operation, particularly in the case of hydro machines, should be carried out easily because it is necessary frequently to observe whether jets are functioning or not. The provision of adequate inspection windows is now an accepted feature of all modern bottle-washing machines, and in some cases the manufacturers are tending to go to great lengths to make the whole of the operations visible from the outside. Where hard waters are used, it is important to see that the windows do not become scaled on the inside, and here again, it is necessary to use the correct detergent and/or to treat the water in such a way that the windows will be always transparent. The provision of adequate manholes and covers to ensure the easy cleaning of the machine is also vital. Only too frequently outbreaks of serious bacterial infection in bottle-washing machines are traced to imperfect cleaning. The practice of cleaning out the machine varies from dairy to dairy. In a few the machine is thoroughly cleaned and scoured out each time the detergent solution is changed, in others this is done once a week, or once a fortnight, and only too often less frequently than that. Sometimes it is the detergent tank which gets most attention, and only too often is the frequency of cleaning conditioned by the accessibility of the inside of the machine. Here again, modern practice is to provide apertures sufficient inside to admit in the larger machines a man to the inside of the tank, and in the smaller types to ensure that the hose and brush can reach all parts of the tank. A powerful hose for flushing and a thorough scrubbing of all accessible parts is the best method, and in addition an occasional monthly boil out, not only of the detergent tank, but of the rinse tank as well, is a great help. For this purpose, of course, no bottles are in the machine and all tanks are charged up with detergent solution at say 2 per cent., and the temperatures in all tanks allowed to go to the maximum possible, and if it is possible to run this for an hour, the benefit to the machine will be unquestionably noticed in the next series of bottle counts. For hydro machines it is important to clean the jet pipes and the jets and to be certain that there is no accumulation of bacteria-bearing deposit inside the pipes and jets, and this is particularly important in the warm rinse sections, and sometimes even in the final mains rinse it is found that the inside surface of the jet contains a little slime which is very rich in bacterial population. Hence, it is important that jets should be boiled out at reasonably frequent intervals, or otherwise cleaned and disinfected, and for this purpose sodium hypochlorite solution is very useful. When a new machine is installed it will often contain traces of oil, grease, swarf, fluff, and all the other contaminants which machining and packing can confer upon a new piece of engineering mechanism. Some considerable degree of bacteriological infection can also be anticipated, and it is important that the machine should be degreased and boiled out first before it is charged with detergent and brought into operation.

Bacteriological Problems. Assuming the only criterion of the success of the bottle-washing operation is the bacteriological condition of the bottles, and in this respect it is only necessary to say that the local sanitary authorities keep a fairly sharp eye on this condition, and since persistently bad counts give rise to the suspicion that there is some focus of infection in the machine, it is best for an experienced bacteriologist to carry out a thorough investigation, swabbing and taking samples from all parts of the machine in order that the source of infection may be traced. Here again, the Ministry of Agriculture Advisory Bacteriologists are usually very willing to render all the assistance they can, while the detergent manufacturer may also run a bacteriological service. Bottles may be either taken from the machine straight to the laboratory and there rinsed and plated, or they may be rinsed at the dairy and then the Ringer solution taken to the laboratory for plating. There is little to choose between the two methods, but the great rule in both cases is to ensure that there is no subsequent contamination once the bottle has been taken from the machine. If the bottle is to be taken away, then it should be aseptically sealed in such a manner that no further bacteriological contamination can take place. Sometimes the ordinary cardboard disk is used to seal the bottle, but this practice can only be frowned upon because of the risk of contamination from the fingers of the person fitting it, if from no other cause.

Water Supplies. Frequent reference has already been made to the importance of the water supply for the bottle-washing process. Since most waters in this country are, to some extent, hard, it is most important that the degree of hardness be known and that the detergent should be blended with a view to preventing the deposition of lime scale. The use of the polyphosphates in this connection is important (*see* Detergents). Water-softening plants can also be used, and although few dairies are sufficiently large to use the lime-soda process, a large number use base exchange plants where Zeolite removes the hardness from the water. The dosing of the water supply by means of solutions of polyphosphates is sometimes carried out, but as a rule this method is found expensive unless it is only for the treatment of water which remains below 80° F., in which case the economical threshold treatment can be used. Water which is pumped from wells is often stored in storage tanks at a high level in the dairy, and gravity fed from there to various plants. In this case it is most important that the tank should be regularly inspected, and if necessary chlorinated to prevent the growth of bacteria. It is also useful, where the supply is from a well, to have the water analysed once or twice a year in case there is any variation in mineral content. This is quite common with well waters. Usually the supply to most bottle-washing machines is mains water, in which case there is no trouble about the bacteriological condition, but it is important that the degree of hardness and the mineral salt content should be known.

Sometimes a source of infection in water supplies is due to the Zeolite in the water-softening plant, where this is of the base exchange type, becoming infected, and in this event sterilisation of the water softener may be effected by permitting contact between water containing about 30 parts per million of available chlorine with the softener bed for a period of about an hour.

" Yellow Spot ". One of the most serious bacteriological troubles met with in bottle washing is an outbreak of " yellow spot ". The yellow spot organism (*Sarcina lutea*) is *not* pathogenic, but can affect the keeping quality of milk. In addition its presence shows that the washing conditions are unsatisfactory and that heavy infections of all kinds of organisms may be expected. In this connection it acts as an indicator, and the colonies which grow in the milk bottle are often very resistant to the detergent solution, and as a result the milk, when filled into the bottle, shows up the streaks and patches of yellow formed by colonies of the organisms. When an outbreak of yellow spot occurs in a machine it must be at once subjected to a thorough cleaning out followed by a thorough boiling out of all tanks with 3 or 4 per cent. solution of a powerful detergent. The machine should be run at the maximum possible temperature for at least three hours without washing bottles, and then the solution drained off and the tanks and carriers and all accessible parts thoroughly hosed down with clean water. This should be followed by a cold disinfection with a solution of sodium hypochlorite which contains 200 parts per million available chlorine. This solution should be filled into all tanks, and the pumps and conveyors run for a further hour when, upon running off the solution, the machine can be re-charged at once ready for operation. For the next two or three weeks detergent temperatures must be maintained as high as possible, and if there is a warm rinse tank this should be boiled out with detergent after each day's run, dosed regularly with sodium hypochlorite solution, and a concentration of 50 parts per million available chlorine maintained. The detergent solution should be changed daily during this period. Bottles which are badly infected with " yellow spot " should be hand cleaned before passing through the machine, and the following treatment is found satisfactory: firstly, soak the bottle in a hot detergent solution ; secondly, thoroughly brush the bottle by hand-dipping the bottle into a hypochlorite solution containing 200 parts per million of available chlorine between each brushing. When all the " yellow spot " has been removed, the bottle should be given a final rinse in a clean 200 parts per million solution of sodium hypochlorite, and then sent through the bottle-washing machine in the usual way. Badly infected bottles should not be stacked in the dairy as this infection is virulent and once having a firm hold will be extremely difficult to stamp out. It is understood in the above remarks that the water in the warm rinse tank will be regularly changed each day as should be the regular practice.

Bottle-washing Detergents. Bottle-washing detergents have developed in the past twenty or thirty years from simple caustic soda or sodium carbonate to compounds which contain varying proportions of caustic soda, various silicates, ortho phosphates, polyphosphates, sodium carbonate and neutral salts, and wetting agents. In general, these can be obtained in three conditions: (1) as powders, (2) as starch gels, and (3) as liquids. All three types have their merits and uses, and reference is made once more to the fact that the machine, water supply, and the bottle, are all factors which have to be considered when prescribing the correct detergent for any bottle-washing process. Powder detergents are popular because they often create the impression of excluding unnecessary water, but the materials of which powders can be made often contain water of crystallisation, and it is possible to formulate an apparently solid powder detergent which, in reality, contains over 50 per cent. of water as water of crystallisation. The efficiency of a bottle-washing detergent cannot be judged by an examination of the formula from which it is prepared, and for this reason there is little point in the detergent manufacturer disclosing his formula. By varying the constituent substances in the detergent very different results can be achieved as regards cleaning power, because when dissolved in water these compounds can react to some extent with each other, forming more complex ions, which would appear to influence or determine the detergent properties of the solution, and the question of complex anion formation would appear, at the moment, to give the best lead to researches into the fundamental principles of detergent action where detergents containing mixed alkalis are involved. Starch gel detergents have great value in that their powers of deflocculation are high, and they are valuable in that they impart to the solution colloidal features which assist the detergency process. Their high powers of deflocculation also assist the prevention of scale formation in machines, and were a most outstanding property before the hexametaphosphate and other polyphosphates became prominent in detergents. They have the additional advantage of being easy to handle, readily soluble, and capable of storage for long periods without deterioration. Liquid detergents are very much less frequently met with in dairy bottle washing than in the other bottle-washing trades. They are invariably much simpler in composition than either the gels or the powders, and have as their great merit the fact that they can be readily poured into the tank of the machine without any trouble with regard to removal from the drum or dissolving in water. It is true to say that the greatest advances in balanced bottle-washing detergents in the last few years has been made with powder detergents, but this does not preclude the possibility of developments with the other types. In the dairy there is a definite inclination to view the NaOH content of the detergent solution as the sole index of killing power, but although caustic soda remains the basis of all efficient bottle-washing detergents, the other substances used can play a very important part in enhancing its power as a bactericide.

Mattick and Sharpe (*SAB* (1939), p. 38) pointed out that in a detergent containing caustic soda and trisodiumphosphate when the solution contains 0·4 per cent. NaOH and 0·05 per cent. Na_3PO_4, then there is little difference between the killing power of this solution and one which contains only 0·4 per cent. NaOH; when the solution contains 0·1 per cent. Na_3PO_4 in addition to the 0·4 per cent. NaOH, however, then the killing power of this solution is significantly greater than that of the 0·4 per cent. caustic soda solution. Reference has also been made (*see* Detergents) to the effect of reducing the surface tension of the alkaline solution. Since bottle-washing detergents at present contain strongly alkaline materials, caution must be observed in handling these, and contact either of the detergents themselves, or of their solution with the skin, should be avoided. Immediately contact has been made, however, immediate washing in running water is essential. A weak solution of acetic acid may also be applied, and operators should be warned to exercise care where there is any danger of the splashing of hot detergent solution from the machine. To sum up, the bottle-washing detergent should be selected, bearing in mind the make of machine, its lubrication needs, its tank and temperature sequences, the hardness and chemical composition of the water to be used, and local conditions involving storage space, humidity, and convenience in filling the machine. *See* Cleaning and sterilising ; Detergents ; Effluent ; Quaternary ammonium compounds ; Water supplies.

Ref. : Thomas *et al.* (1947), *SAB*, p. 6 (sterilisation).

BOTULISM. *See* Food poisoning.

BOURDON COIL, GAUGE. *See* Instrumentation.

BRAN. Wheat bran is a concentrate which is of high phosphorus and low calcium content and contains a moderate amount of digestible protein. *See* Feeding.

BRASS. An alloy of about 2 parts copper and 1 part zinc. Its use in dairy equipment should be avoided on account of the ease of corrosion and the possible copper contamination of the milk.

Ref. : Evans.

BRAZIL, DAIRYING IN.

Refs.: Ballarin (1953), *DSA*, **15**, 749, 833; Minut (1951), *M*, **6**, 10, 43, 86; Frensel (1949), *IDC*, **5**, 203; Herz, 210.

BREADMAKING, MILK CONSTITUENTS IN. Milk or milk products have been used as ingredients of bread doughs only to a very small extent in Great Britain. During the war, milk powder was added to National flour by the miller at the rate of 2 lb. per 280 lb. of flour, but this was a temporary measure (December 1942 to March 1944) introduced to salvage Government stocks of milk powder which, owing to slow retail sales, would have become unfit for use while in store. In America, however, the position is very different and milk solids are in general use as a bread ingredient. The annual production of non-fatty dry milk solids in America is in the region of 300,000 tons and only about 25 per cent. of this is exported. The American Dry Milk Institute has accordingly made strenuous efforts to build up home markets for non-fatty dry milk solids and particular attention has been given to the baking industry. To-day, this industry absorbs about two-thirds of the total non-fatty dry milk solids used domestically and, indeed, accounts for approaching half of the total production.

The dry milk products which are in general use throughout the American baking industry as standard ingredients of bread doughs are employed in proportions which lead to the presence in the dough mix of 6 per cent. of non-fatty dry milk solids calculated on the weight of the flour. The reason for the adoption of this level of enrichment is that it corresponds to the proportion of non-fatty milk solids which would be present in the bread were the dough made with whole milk in place of water.

There are two aspects of the use of milk products in breadmaking which call for consideration when the merits of the practice are under review. That consideration has to be given to the nutritional aspect is obvious, but it may be less obvious that the effects of the addition upon dough and loaf quality is a factor of importance. The addition to a bread dough of a substance which enhances the nutritive standard of the loaf would be of little value if, by alteration of the dough properties, it made the baker's task more difficult or, alternatively, if it significantly affected loaf quality in the direction of impairment of eye and palate appeal.

The nutritional advantages attaching to the use of a significant proportion of milk products in a bread dough are the introduction of good quality protein; mineral matter, particularly calcium; riboflavin, vitamin B_1 and other water-soluble vitamins. Thus, the use of 6 per cent. skim milk powder in a white flour dough, as is practised in America, yields bread containing four to five times as much calcium, about two-and-a-half times as much riboflavin and one-and-one-third times as much vitamin B_1 as white bread made without the milk product addition. The addition also raises the protein content of the white bread by just over one unit per cent. If 6 per cent. dried whey be used as a dough addendum instead of 6 per cent. skim milk powder, the protein content of the bread is not increased but the calcium content is increased to about two-and-a-half times its previous level, while the vitamin B_1 and riboflavin contents are raised to about the same extent as they are when 6 per cent. skim milk powder is employed.

The statement has often been made that milk protein has a supplementary effect on cereal proteins and that, in consequence, the biological value of a mixture of milk and flour proteins is appreciably greater than the value calculated from the biological values of the two components of the mixture. Recorded data indicate that whether or not a supplementary effect exists depends upon the proportion of the total protein intake represented by the milk product. When milk forms 20 per cent. or more of the protein intake, supplementary relationships can be demonstrated, but when only about 10 per cent. of the protein is represented by milk protein, there is no supplementary effect. (Henry, Houston, Kon, Powell, Carter and Halton ; Henry, Kon and Rowland; Henry and Kon.)

From the nutritional angle, therefore, the advantages of incorporating dried skim milk or dried whey in bread are a considerably greater calcium content and a significant increase in riboflavin and other B vitamins; dried skim milk also raises the protein content.

The introduction of skim milk powder into a dough at the 6 per cent. level has a significant effect upon the physical properties of the dough. The dough is initially rendered more stable and requires in the region of an extra gallon of water per sack. During fermentation, however, the dough slackens markedly and becomes very extensible. Oven jump is diminished and a smaller loaf results; the crumb is closer, tighter and darker in colour. The inclusion of dried whey at the same level leads to an even greater diminution in loaf volume and may give rise to a coarser texture in the crumb, which will be darker in colour. This addition also imparts to the bread a marked flavour which most people would find objectionable.

The effect of these milk products upon the dough and upon the loaf can be offset by the inclusion of fat in the formula. To overcome the effect produced by the addition of 6 per cent. skim milk powder, it is necessary to use about 1 per cent. of fat. The compensating effect of fat explains why American bread which contains 6 per cent. of dried milk solids is bold and has a good colour and texture in the crumb; it is the usual practice in the U.S.A. to use not only 6 per cent. of non-fatty milk solids but also 6 per cent of fat.

It was shown over twenty years ago that the detrimental effect of non-fatty milk solids upon the properties of a dough and upon loaf quality could be diminished by heat treatment of the skim milk prior to drying (Greenbank, Steinberger, Deysher and Holm ; Grewe and Holm). In order to obtain a significant improvement in the baking quality of the resultant skim milk powder, the skim milk needed to be raised to at least 73° C., at which temperature 30 min. heating was necessary; at a temperature of 93° C., only 1 min. heating as required.

Subsequent studies in America (Stamberg and Bailey; Harland, Ashworth and Golding) revealed that much of the harmful effects of skim milk powder prepared from unheated skim milk upon dough and loaf was attributable to the serum protein fraction. Casein and lactose cause some reduction in loaf volume, but their effects in this direction, unlike those of the whey fraction, cannot be altered by heat treatment. (Larsen, Jenness and Geddes, 1949.) A finding of significance (Larsen, Jenness and Geddes, 1949*a*) was that the heating led to a decrease in the titratable —SH groups. Compounds containing sulphydryl groups can cause dough softening and can lead to diminution in loaf volume and it seemed, therefore, that the improvement in baking quality which results when skim milk is suitably heated before being dried was probably due to a reduction in the activity of the —SH groups of the milk serum proteins.

Although the extent to which the heat treatment leads to denaturation of the serum proteins is closely related to the effect of the milk powder on dough and loaf quality, it has not been proved that the factor which determines the baking quality of a heated milk powder is its actual content of undenatured whey protein. It has been suggested (Larson, Jenness, Geddes and Coulter) that the improvement in baking quality may be due to another change which runs parallel to the denaturation of the serum proteins and that the value of a knowledge of the latter lies in its being an index of the progress of the heat treatment. It has been claimed (Ashworth and Krueger) that when denaturation is achieved by heat treatment at 80° C. for at least 15 min., best baking results are obtained when the denatured whey protein nitrogen is less than 2 mg. per g. of non-fatty milk solids.

Refs.: Ashworth, U. S. and Krueger, G. J. (1951), *Cer. Chem.*, **28**, 145; Greenbank, G. R., Steinbarger, M. C., Deysher, E. F. and Holm, G. E. (1927), *JDS*, **10**, 335; Grewe, E and Holm, G. E. (1928), *Cer. Chem.*, **5**, 461; Harland, H. A., Ashworth, U. S. and Golding, N. S. (1943), *Cer. Chem.*, **20**, 535; Henry, K. M., Houston, J., Kon, S. K., Powell, J., Carter, R. H. and Halton, P. (1941), *JDR*, **12**, 184; Henry, K. M., Kon, S. K. (1949), *JDR*, **16**, 53; Henry, K. M., Kon, S. K. and Rowland, S. J. (1946), *JDR*, **14**, 403; Larsen, R. A., Jenness, R. and Geddes, W. F. (1949), *Cer. Chem.*, **26**, 189; Larsen, R. A., Jenness, R. and Geddes, W. F. (1949), *Cer. Chem.*, **26**, 287; Larson, B. L., Jenness, R., Geddes, W. F. and Coulter, S. T. (1951), *Cer. Chem.*, **28**, 351; Stamberg, O. E. and Bailey, C. H. (1942) *Cer. Chem.*, **19**, 507.

BREAST FEEDING. The advantages of breast feeding over bottle feeding are: (i) human milk is more suitable chemically than cow's milk for the human suckling; (ii) there is less danger of disease, especially of the food poisoning type. *See* Human milk; Infant foods; Nutritive value.

Refs.: Kon and Mawson; Platt and Moncrieff (1947), *Brit. Med. Bull.*, **5**, 177; Waller (1947), *ibid.*, 181; Mackintosh (1947), *ibid.*, 185.

BREED COUNT. *See* Microscopic (direct) count.

BREEDS, COMPOSITION AND YIELD OF MILK.

TABLE Be 1

AVERAGE COMPOSITION OF MILK OF FIVE BREEDS OF COWS

(American values from Rogers)

Breed	*Water*	*Total solids*	*Fat*	*Protein*	*Lactose*	*Ash*
	%					
Guernsey . .	85·13	14·87	5·19	4·02	4·91	0·74
Jersey . . .	85·31	14·69	5·18	3·86	4·94	0·70
Ayrshire . .	86·89	13·11	4·14	3·58	4·69	0·68
Holstein (Friesian)	87·50	12·50	3·55	3·42	4·86	0·68
Shorthorn . .	87·43	12·57	3·63	3·32	4·89	0·73

No accurate figures are available for the total numbers of cows of each breed in Great Britain but Table Be 2, which gives the numbers of licensed bulls of each breed, permits an estimate of the relative numbers of cows of each breed.

The total yields for the first three lactations for the chief breeds in the U.K. for different ages of first calving are given in Table Be 3, and the relation of fat percentage in the milk to milk yield for first calf heifers is illustrated in Table Be 4.

TABLE Be II

TOTAL BULLS LICENSED—ENGLAND AND WALES—(1934–50)

(Ministry of Agriculture and Fisheries)

Breed	1934	1941	1945	1950
Ayrshire .	192	750	2,684	3,115
Friesian .	1,210	6,125	8,220	9,308
Guernsey	969	1,037	1,219	1,582
Jersey	328	369	548	944
Red Poll	417	377	467	425
Shorthorn	13,908	21,023	14,593	7,902
A Angus	635	512	458	439
Hereford	1,806	2,191	1,740	1,784
Others	3,142	4,172	3 260	2,043
Total	22,607	36,556	33,189	27,542

TABLE Be III

TOTAL YIELD IN THE FIRST THREE LACTATIONS COMBINED

Breed	*Age at first calving*					*Average*
	24 26 mths	*27 29 mths*	*30 32 mths*	*33 35 mths*	*36 38 mths*	
	Yield (lb)	Yield (lb)	Yield (lb)	Yield (lb)	Yield (lb)	Yield (lb)
Ayrshire	22,940	22 986	22,876	23 557	23 528	23 280
Friesian	24,665	25 059	25,287	26,273	26,498	26 868
Shorthorn	18 922	19 640	19,524	20 449	20 495	20,174
Red Poll .	18 850	19,274	19,941	20 501	18,877	19,651
Guernsey	20 008	20 117	20,998	22,139	20 609	20 883
Jersey	18 958	18 561	18,835	20,123	20 329	19,008

TABLE Be IV

THE RELATIONSHIP OF FAT PER CENT TO MILK YIELD (FIRST CALF HEIFERS)

Yield group lb of milk	*Ayrshire*		*Friesian*		*Guernsey*		*Jersey*		*Shorthorn*	
	No of animals	*Fat %*	*No of animals*	*Fat*	*No of animals*	*Fat*	*No of animals*	*Fat*	*No of animals*	*Fat*
Under 5,000	1,531	3 95	1 708	3 58	716	4 65	1 796	5 08	2 253	3 65
5,000	1,393	3 96	1 405	3 58	766	4 68	1 303	5 12	1 896	3 65
6,000	2 123	3 93	2 354	3 56	1 083	4 62	1 178	5 04	2 400	3 64
7,000	2,360	3 93	2 862	3 54	990	4 59	754	4 94	1 952	3 60
8,000	1,941	3 90	3 123	3 53	599	4 57	338	4 81	1 112	3 56
9,000	1 103	3 84	2 536	3 50	282	4 45	98	4 68	446	3 54
10 000	589	3 81	1,677	3 53	89	4 35	30	4 66	191	3 46
11,000	178	3 72	979	3 43	19	4 32	6	4 71	46	3 53
12,000	49	3 62	518	3 39	5	4 15	2	4 03	7	3 23
13,000 and over	34	3 61	435	3 33	2	4 02	1	3 82	5	3 65
Total	11,301	3 91	17,597	3 53	4 551	4 60	5,506	5 03	10,308	3 62

See Breeding, Composition, factors affecting, Quality payment

Ref Davis (1952), *A*, 77, 499

BREEDING OF DAIRY CATTLE. The natural attributes of the bovine species make it remarkably well suited to domestication, and these attributes can be further modified and developed by breeding. In earlier days the cattle of Great Britain were used for three main purposes, *viz.* for work, for beef, and for milk production, but their use for work has now become a relic of the past. A breeding problem which has been debated repeatedly throughout the present century is whether it is better, in this country, to try to combine both beef and milk producing qualities in one animal, *i.e.* " dual purpose ", or to concentrate either on beef or on milk in a " single purpose " animal. There is a widespread —and probably a well-founded—belief that " beef " and " milk production " are mutually antagonistic, and there is no doubt that during the first half of the twentieth century there has been a marked increase in the popularity of " single purpose " cattle in Great Britain, especially the dairy type. When viewed solely from the genetic angle, it is far easier to breed cattle for one than for two purposes, and in practice, breeders of single purpose cattle usually attain better beef or greater milk production than those who breed dual purpose cattle.

The productive capacity of dairy cows is extremely variable; a poor producer may yield as little as 1000 lb. milk in a year, while yields as high as 30,000 lb. are not uncommon. The average yield of dairy cows in Great Britain is not known with certainty, but it is approximately 5000 lb. per cow, and the average butterfat percentage is about 3·8. A few superior herds maintain an average yield of over 10,000 lb. milk per cow per year (Table Br I).

The milk of high yielding cows tends to contain a lower proportion of total solids than the milk of low yielders, and a limiting factor in productivity appears to be the ability of the cow to convert the nutrients of her food into milk solids.

The production of both quantity and quality of milk are inherited characteristics and therefore can be improved by suitable breeding. A breeding programme for dairy cattle may be considered in three sections: (i) formulation of a precise objective as to the qualities of the animal to be bred, (ii) methods of selection, and (iii) systems of breeding.

1. **Qualities of Dairy Cattle.** A clear conception of what is required is a pre-requisite of any operation, and it is essential, though difficult, for the breeder of dairy cattle to envisage and to express the exact qualities of his ideal dairying animal. A scheme frequently used for training students to observe the essential features of a dairy cow is a score card such as that given below. This was originally published in *Agricultural Progress*, 1930, vol. vii, p. 101. It indicates by means of a scale of points the relative importance of each feature.

STOCK-JUDGING SCORE CARD FOR DAIRY COW OR HEIFER IN MILK

	Points
General appearance (20)	
Health, style and colour. A healthy " bloom "; active stylish carriage; not nervous. Colour attractive	5
Form. Wide, deep, well-balanced	5
Quality. Hair soft and fine; skin thin and loose; bone fine and clean .	5
Evenness of flesh	5
Head and Neck (12)	
Head. Feminine, clean cut; face fairly long from eyes to nostrils; forehead broad, slightly dished; eyes large and clear, with a gentle expression; nostrils wide and expansive; muzzle wide; ears of good size and rising slightly upwards. Horns fine	8
Neck. Lean, but not weak, fairly long, clean at junction with head, no noticeable amount of dewlap	4

STOCK-JUDGING SCORE CARD—*Contd.*

	Points
Forequarters (9)	
Shoulders. Light, neat on top, smoothly blended with body	3
Chest. Deep, wide between and behind the forelegs, full behind the shoulder-blades. Brisket light	6
Body (12)	
Back. Level, straight, broad and strong at the loin	5
Ribs. Long, deep, well sprung, giving a capacious barrel	7
Hindquarters (14)	
Rump. Long, broad and level	7
Pin-bones and thighs. Pin-bones wide apart, and thighs deep, not too fleshy	5
Tail. Neatly and well set in; fine	2
Legs (3)	
Well apart and short; shank fine and smooth, feet strong and sound .	3

TABLE

PRINCIPAL FEATURES OF DUAL PURPOSE

Breed	" *Milk* ", " *Beef* ", *or* " *Dual purpose* "	*Colour*	*Size* [1]	
			Mature live weight lb.	*Height at withers in.*
Ayrshire .	Milk	Red and White or Black and White. Never roan	1270	52·0
British Friesian .	Milk	Black and White	1480	55·0
Dairy Shorthorn .	D.P.	Red, Roan, White, or Red and White	1400	53·0
Devon . . .	Beef and D.P.	Red	1370	50·0
Dexter . . .	D.P.	Black and occasionally Red with little White	760	40·7
Guernsey . .	Milk	Fawn or Yellowish Red with distinct patches of White	1130	50·8
Jersey . . .	Milk	Fawn of various shades, Grey, and some with dark Brown patches. Rarely any White	920	48·0
Kerry . . .	Milk	Black	980	48·1
Lincoln Red Shorthorn	D.P.	Red	1390	53·3
Red Poll . .	D.P.	Red. No horns	1320	51·2
South Devon . .	D.P.	Light or Yellowish Red	1620	55·0
Welsh Black . .	Beef and D.P.	Black	1350	51·0

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[1] Based on first prize winners at London Dairy Show, 10 years, 1928–37.

[3], [4], [5] Mean yields during one day in early lactation of all cows in the milking

STOCK-JUDGING SCORE CARD—*Contd*

Milk Vessel (30)

	Points
Udder. Skin thin, soft and elastic, hair fine and silky, udder long, wide and deep, extending well up behind and far forward. Quarters even, and free from fleshiness. Udder veins plainly visible	20
Teats. Correct size, uniform and evenly placed, yielding milk freely .	6
Milk veins. Prominent and well developed, and the milk wells large	4
	100

Deduct

For each serious defect, *e g* size for age, unhealthiness, overfat, etc, deduct up to	15
In a pedigree animal deduct for absence of breed points and lack of conformity to breed type, up to .	15

The above score card is intended to apply to any dairy cow, but in practice it is more convenient for the breeder to select one of the established breeds and to base his ideal animal on the descriptions laid down by the breed society which

Br I

and Dairy Breeds of Cattle in Great Britain

2 Average yearly milk yield lb	3 Milk yield in 24 hrs lb	4 % fat in milk	5 % solids-not-fat in milk	Locality	Herd book established
7215	44.8	3.60	9.05	South-West of Scotland and other parts of Great Britain	1877
8363	54.6	3.47	8.74	Throughout Great Britain	1912
6597	48.0	3.63	9.08	Throughout Great Britain	1822
5340	40.2	3.88	9.13	North Devon and elsewhere in Great Britain	
4115	29.6	3.83	9.06	Southern Ireland. A few ornamental herds in Great Britain	1890
6882	36.3	4.53	9.26	Island of Guernsey and southern half of Great Britain	
6611	35.9	4.86	9.20	Island of Jersey and southern half of Great Britain	1866
6652	34.6	3.90	9.12	West Ireland and few herds in Great Britain	1890
6539	52.3	3.52	9.02	Lincolnshire and few herds elsewhere in Great Britain	1895
7113	43.4	3.68	9.03	Eastern counties of England and few herds elsewhere	1874
6011	50.1	3.81	9.16	South Devon. Very few elsewhere	
5128			–	Wales	1904

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[2] Average yearly yields recorded by National Milk Records 1945-46

trials at the London and the Royal Shows during the twenty Shows 1909 to 1921

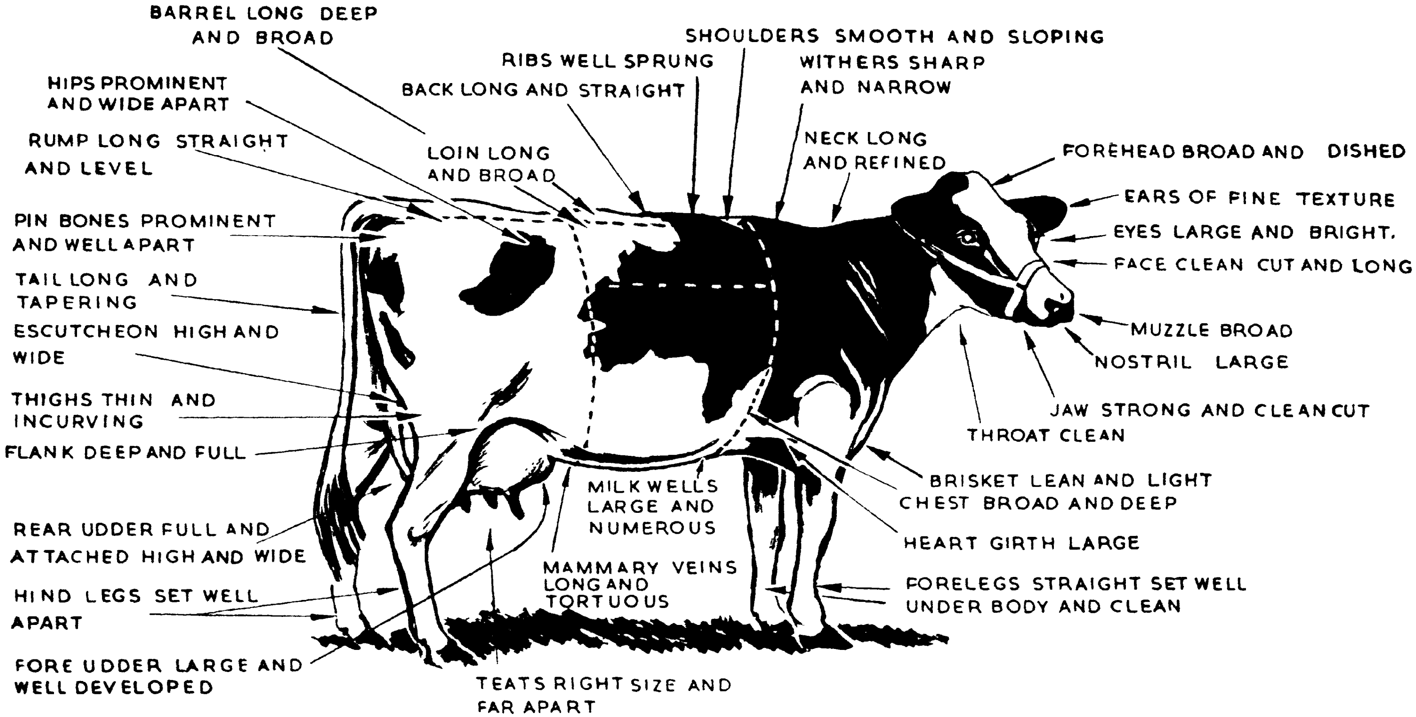

BARREL LONG DEEP AND BROAD
HIPS PROMINENT AND WIDE APART
RUMP LONG STRAIGHT AND LEVEL
PIN BONES PROMINENT AND WELL APART
TAIL LONG AND TAPERING
ESCUTCHEON HIGH AND WIDE
THIGHS THIN AND INCURVING
FLANK DEEP AND FULL
REAR UDDER FULL AND ATTACHED HIGH AND WIDE
HIND LEGS SET WELL APART
FORE UDDER LARGE AND WELL DEVELOPED
TEATS RIGHT SIZE AND FAR APART
MAMMARY VEINS LONG AND TORTUOUS
MILK WELLS LARGE AND NUMEROUS
LOIN LONG AND BROAD
BACK LONG AND STRAIGHT
RIBS WELL SPRUNG
SHOULDERS SMOOTH AND SLOPING
WITHERS SHARP AND NARROW
NECK LONG AND REFINED
FOREHEAD BROAD AND DISHED
EARS OF FINE TEXTURE
EYES LARGE AND BRIGHT.
FACE CLEAN CUT AND LONG
MUZZLE BROAD
NOSTRIL LARGE
JAW STRONG AND CLEAN CUT
THROAT CLEAN
BRISKET LEAN AND LIGHT
CHEST BROAD AND DEEP
HEART GIRTH LARGE
FORELEGS STRAIGHT SET WELL UNDER BODY AND CLEAN

FIG. BR 1.—*The Points of a Dairy Cow.*

A Dairy Cow should have Large Capacity for Feed, a Dairy Temperament, Well-developed Milk Organs, Fine Quality, Perfect Health and be capable of a Large Production of Milk and Butter Fat.

appears to be nearest to his own objective. The methods normally used by the breed societies to standardise their breed are to publish a description of a typical animal of their breed and to appoint a panel of judges who are considered competent to interpret these descriptions and to decide whether an animal is or is not typical. The breed societies also publish reliable genealogical or pedigree records of all their cattle, and frequently sponsor schemes to record and thereby to improve, milk-producing qualities. Descriptions of the conformation of a dairy cow tend to be somewhat nebulous; colour is much more specific and is usually stated with clarity; size is controlled more by tradition than by rigid rules, with the result that appreciable variation is found.

A novel and effective plan for illustrating an ideal animal was that adopted by the American Holstein Friesian (cattle) Breed Society; they appointed a team consisting of a number of recognised cattle judges, a sculptor and a painter. After inspecting a number of almost typical animals and agreeing as to which of their features were perfect and which were imperfect, the sculptor produced a model and the painter a painting of the ideal Holstein Friesian cow and bull. Reproductions of this model and painting provide breeders with a clear illustration of the ideal animal. (*See* Fig. Br. 1.)

In addition to specifications of appearance and conformation, the breeder can formulate the level of milk yield and quality which he intends his animals to attain. Many of the breed societies lay down minimum yields, usually varying with age of cow, which they consider necessary for their breed, but both breed societies and breeders usually assume that it is unnecessary to state any upper limit of milk production. This is understandable in view of the fact that the highest yielding cow tends to be the most economical milk producer, but failure to aim for a definite optimum yield must react against uniformity in the animals which are being bred.

2. **Methods of Selecting Dairy Cattle.** The ability to assess in the living animal the presence or absence of desirable qualities and thereby to select superior animals from which to breed the next generation is essential for successful breeding. There is no single method which can be relied upon and therefore the breeder must combine all the methods at his disposal. These include:

(*a*) *Study of the visible qualities which are observable by inspection of the animal and which have been outlined in the preceding section.* In the early years of this century many breeders relied almost entirely on this method of selection. No doubt this was due to its successful use in the breeding of beef cattle, but unfortunately visible characters were soon found to have little or no correlation with milk-producing abilities, with the result that some authorities then condemned inspection as a stumbling block rather than an aid to the selection of dairy cows. Most breeders now consider that in spite of the fact that appearance is a poor guide to milking ability, the inspection of a dairy cow can indicate a number of essential features, *e.g.* general condition of health, growth rate as shown by size for age, and the presence or absence of constitutional weaknesses such as weak legs or a misshapen udder.

(*b*) *Study of the accomplishments of the animal.* The outstanding requirement of a dairy cow is, of course, the production of milk. Cows normally produce their first calf at 2½ to 3 years of age, and thereafter should calve at intervals of 11 to 15 months. Milk secretion is highest during the 2 or 3 months after calving and then gradually declines. Fertility is essential in dairy cattle because pregnancy and parturition are necessary preludes to milk secretion. Infertile cows cease to be profitable producers of milk about one year after their last calving. The most reliable criterion of the accomplishments of a dairy cow is provided by her lifetime milk records. These indicate productivity by a statement of the quantity and often the quality of the milk produced in each lactation. Fertility is also recorded by the number and regularity of calvings; also the constitution of the animal may be judged by the level of production combined with the length of productive life. Organisations for encouraging and checking the milk records of cows exist in most of the dairying countries of the world. In England and Wales the Milk Marketing Board controls milk recording, and in Scotland the work is organised by the Scottish Milk Records Association, Ayr. The records provided by these Associations are utilised by all breeders of dairy cattle and by the various breed societies as the basis of their schemes for selecting and breeding more productive dairy cattle.

(*c*) *Study of ancestors and relatives, in order to observe the nature of the heritable factors or genes which are tending to be passed through the successive generations of the family.* The genealogical records of certain cattle are kept by the breed societies, and when these are coupled with milk records, it is possible for the breeder to observe the names and productivity of the relatives of any animals. Knowledge of some of the principles of genetics is necessary for the most effective use of this form of selection. The heritable qualities of animals are transmitted from parent to offspring by the germ cells. These factors are called genes; they are very minute and it is now considered possible that they are exceptionally stable molecules of protein. The only known method of differentiating desirable from undesirable genes is by noting the observable qualities of the animal which is carrying them. Thus, study of the ancestors of an animal can indicate the kind of germ cells or genes these animals would be likely to transmit, the study of the progeny can indicate the kind of genes which are actually being transmitted. It has been repeatedly shown that progeny provide a much more reliable guide than ancestry as to the genetic make-up of an animal.

3. **Systems of Breeding.** The mechanism which controls breeding and inheritance is extremely complex and there is no infallible breeding system which will ensure success. The laws of chance play a large part in inheritance, but skilful breeding can gradually mould successive generations in the desired direction. One system of breeding is based on constant selection and the mating together of the animals so selected. The success of this or any other system depends on the genes or the genetic make-up of the animals concerned and the breeder's ability to select and mate these animals. A major feature in systems of breeding is the degree of relationship between the animals which are mated. This varies from completely unrelated animals to brother-sister matings.

The following notes deal with some of the systems and terms used in cattle breeding.

Pedigree. The various herd books published by the breed societies show the ancestry or pedigree of approved animals and these are usually termed " pedigree " animals. Considerable care is taken by the breed societies to ensure the accuracy of these pedigrees and this guarantee of reliability marks the essential difference between a pedigree and a non-pedigree animal.

Grading or grading up is the mating of non-pedigree females of a suitable type with pedigree sires. When this is continued for several generations certain breed societies accept the progeny as pedigree animals. Breed societies which admit " grading up " to pedigree status are said to have " Open " herd books, while those breed societies which do not permit " grading up " are said to have " Closed" herd books.

Crossbreeding. This involves the mating of two animals of different breeds. The progeny frequently possess a quality which is known as " Hybrid vigour " but the genetic make-up is so mixed or " heterozygous " that the offspring of crossbred animals are extremely variable. Because of this, crossbreeding is considered undesirable in the breeding of dairy cattle.

Outcross is a term used to indicate the mating of two animals which are unrelated but of the same breed. It is frequently employed and its use is satisfactory and safe in herds of a mediocre standard.

Inbreeding is the mating of closely related animals. The term is usually reserved for matings such as brother to full sister, sire to his daughter or dam to her son. When this system of breeding is practised, the genes contributed by both male and female parents are similar, with the result that when these genes are paired in the offspring, a large proportion of the pairs are made up of identical genes, a condition which is usually termed homozygous.

This concentration of all inheritable factors, both good and bad, which is brought about by inbreeding, frequently produces in the offspring evidence of undesirable recessive characters which were unsuspected in the parents. Inbreeding, therefore, provides an exacting test of the inheritable factors which an animal carries; since nearly all animals possess a proportion of undesirable genes, it follows that inbreeding should only be attempted with the highest grade of animals and even then the chances of success are somewhat remote. A well-known example of successful inbreeding was practised by Bakewell in the eighteenth century, with Shorthorn cattle. There is little doubt that Bakewell's success was largely due to his exceptional skill in selecting cattle, but he may have been lucky as well as skilful, and the reason for the occasional success of inbreeding remained obscure until the science of genetics had provided the general picture of how the genes of an animal are segregated, divided and passed to the next generation in the process of reproduction.

Line breeding is the mating of animals somewhat less closely related than those noted for inbreeding. It is usual to describe a family of animals as " Line bred to a certain animal ", and in practice this usually involves the use of a certain animal as a herd sire followed by one of his direct descendants; thus the blood line of the sire is carried through more than one generation. The method is in good repute and when used by skilful breeders may yield good results. The animal to which a herd is line-bred, however, must possess exceptionally high class genetic qualities and only a limited number of breeders are able to acquire sires of sufficient merit to justify line breeding.

Artificial insemination. Improvements in the technique of artificial insemination which were developed during the nineteen thirties proved to be easily applied to dairy cattle, with the result that the breeding in the dairy herds of Great Britain was almost revolutionised by the process during the nineteen forties. The outstanding advantage of artificial insemination over natural mating is that the number of calves which can be sired by one bull can be increased at least one-hundred-fold, thereby permitting rigorous selection of bulls. Dairy farmers also find the process to be convenient and economical, with the result that cattle breeding centres are now established all over England and Wales and over much of Scotland. Most of the centres are controlled by the Milk Marketing Board and each one provides an insemination service over an area of about 400 square miles. High-class pedigree bulls of certain specified breeds are kept at each centre; cross-breeding is discouraged and the fee in most cases is 25s. per cow for a first insemination, with repeat inseminations, if needed, free of charge.

Official control of artificial insemination is maintained in Great Britain through the Agriculture (Miscellaneous Provisions) Act 1943, and the complementary Statutory Rules and Orders 1943, No. 1122 entitled *The Artificial Insemination (Cattle) (England and Wales) Regulations.* This order prohibits the sale and distribution of bull semen except under licence.

Refs.: Rice, Andrews and Warwick (1953), *Breeding Better Livestock*, New York and London; F. H. Garner, *The Cattle of Britain*, Longmans, Green & Co., London, 1944; *British Pedigree Cattle*, The National Cattle Breeders' Association, 17 Devonshire Street, London, 1946; The Ministry of Agriculture and Fisheries, *British Breeds of Livestock*, Bulletin No. 86, H.M.S.O., 6th edn., 1938.

BRICK. *See* Cheese, p. 184.

BRIE. *See* Cheese, p. 184.

BRINE. Calcium chloride ($CaCl_2$) solution is commonly used in this country as a medium for the transfer of heat from milk. The commercial salt is only 73 to 75 per cent. pure and is hygroscopic, *i.e.* it absorbs moisture from the air.

Although chilled water could with many advantages be used in place of brine for refrigeration in creameries and dairies, brine is still in use in most places and it is advisable to exercise scientific control over two aspects—density and *p*H (or acidity).

Density. This not only affects the heat transfer efficiency of the medium but also controls to some extent the rate of corrosion. Density should be checked every 2 to 4 weeks with a hydrometer and should be maintained between 1·20 and 1·25 (30° to 50° Twaddell). If brine becomes too weak it may freeze.

The following table gives density data for calcium chloride brines.

% $CaCl_2$ by weight	*Pounds pure $CaCl_2$ per gal. soln.*	*Density Sp. gr. at 60° F.*	*Degrees Baumé 60° F.*	*Degrees Twaddell 60° F.*	*Degrees Salometer 60° F.*	*Freezing point ° F.*
3	0·3	1·024	3·4	5	12	29·5
6	0·65	1·049	6·8	10	26	26·6
9	0·95	1·076	10·2	15	40	22·8
12	1·3	1·103	13·5	21	52	18·1
15	1·7	1·131	16·8	26	68	12·2
18	2·1	1·160	20	32	80	4·6
21	2·5	1·188	23	38	92	− 4·9
24	2·9	1·218	26	44	104	− 17·1
27	3·4	1·250	29	50	116	− 32·6
30	3·85	1·283	32	57	128	− 54·4

Corrosion. The most important factor in this is undoubtedly acidity. This is increased by aeration through absorption of carbon dioxide. Particular care should be taken to avoid splashing or sucking in air through leaky stuffing boxes. To minimise corrosion, the *p*H should be maintained between 8·5 and 9 although if only iron is concerned, no harm will arise if the *p*H rises to 10 or 11. High alkalinities are, however, dangerous for zinc, tin, etc., and will produce a sludge due to the precipitation of calcium hydroxide. Although glass electrode measurements are the most accurate, the ordinary comparator, such as the Tintometer or BDH, with a thymol blue disc is quite accurate enough for industrial control. The presence of the salt causes the reading to be about 0·6 *p*H units too high; the brine should therefore be maintained at an *apparent* " thymol blue *p*H " of 9·1 to 9·6.

Apparatus Required. One all-purposes Comparator (Tintometer, Ltd., Salisbury); one thymol blue disc; one bottle thymol blue indicator solution.

Adjustment of Acidity. If the *p*H is less than 8·5 (high acidity) add lime or caustic soda. About 1 lb. slaked lime should be added to 10,000 cu. ft. of brine to raise the *p*H by 1 unit.

If the *p*H is greater than 9 (high alkalinity) the *p*H may be brought down by bubbling carbon dioxide gas (CO_2) through the brine. This is a slow method. The addition of weak hydrochloric acid is quicker but is dangerous, as it is easy to overshoot the end point (*p*H 8). A safe alternative is a solution of sodium dichromate (5 lb. to 1 gal. water) which not only corrects high alkalinity but also acts as a corrosion retarder. In practice it is unnecessary to reduce high alkalinity.

Corrosion Inhibitors. Of these sodium chromate is best and may be prepared by dissolving 100 lb. commercial sodium dichromate in 20 gal. water and adding 30 lb. commercial caustic soda (sodium hydroxide). This quantity is sufficient for 6200 gal. (1000 cu. ft.) of brine and should be run in very slowly while the brine is in active circulation. A replenisher charge of half this amount should be added every year.

Chromates protect against corrosion not only of iron, but also of zinc and aluminium.

Chromate-treated brines should not be allowed to come into contact with the skin for any length of time as an irritation (" chromate itch ") may result. *See* Chilled water; Cooling; Refrigeration.

Refs.: LCDP; Berger and Lindquist (1949), *IDC*, **3**, 540 (K_2CO_3—$NaHCO_3$ brine); Davis (1952), *F*, **21**, 467.

BRINE, TESTS FOR, IN MILK. Brine may enter milk through a pin-hole in the plate of an H.T.S.T. plant and can be detected by (i) increased conductivity, (ii) high ash and especially calcium, (iii) clotting on boiling, and (iv) taste. Brine in milk reduces the heat stability and so can have drastic effect in most types of processing, but especially with evaporated milk. Brine in milk can be confused with *sweet curdling* (*q.v.*).

BRINELL HARDNESS NUMBER. A practical index of the hardness of a metal. It is measured by the ratio of a load in kg. on a sphere used to indent a material to the spherical area of the indentation in mm.^{2}. Typical values are: aluminium 39, aluminium alloys 44-69, chromium 91, brass 95-150, monel metal 110-300, steels 202-627.

BRINSEN. *See* Cheese, p. 185.

BRITISH DAIRYING (Great Britain). *See* Agriculture ; Milk Marketing ; Utilisation.

Refs.: Enock ; Garner (1946), *British Dairying*, London.

BRITISH STANDARDS INSTITUTION, 2 Park Street, London, W.1. This non-profit making body is Government subsidised and performs a most useful function in acting as a liaison organisation for the standardising of equipment and methods in industry. It has a dairy industry committee (*DAC*) which has under it 22 working committees covering many aspects of dairy technology.

BRITISH THERMAL UNIT (B.Th.U.). The amount of heat required to raise the temperature of 1 lb. water 1° F. It is equal to 0·252 Calorie or 252 calories.

BROM-CRESOL PURPLE TEST. *See* Abnormal milk ; Mastitis.

BRONCHO-PNEUMONIA IN CALVES. A disease caused by *Haemophilus bronchisepticus* with a high mortality rate.

Refs.: Miller ; Wilson and Miles.

BROWNIAN MOVEMENT. An irregular oscillatory movement of small particles such as bacteria, caused by the incessant bombardment of smaller, invisible particles. It is important not to mistake this for motility when making hanging drop preparations of bacteria.

BROWNING OF MILK. When heated above 212° F. milk gradually becomes brownish in colour (*cf.* sterilised or autoclaved milk) due to condensation of certain amino acid groupings with the lactose to form humins. *See* Milk powder; Sterilised milk.

BRUCELLA. *See* Abortion ; Undulant fever.

BRUCELLOSIS. A general term for a *Brucella* infection.

BUDDE'S PROCESS. The preservation of milk by the addition of hydrogen peroxide (H_2O_2) and heating to 50° to 55° C. to complete the catalase reaction. The action is a complex one and probably involves the heating and rupture of the bacterial cells as well as a purely chemical reaction. *See* Hydrogen peroxide.

BUFFALO'S MILK. In some countries, such as India, buffaloes form an important source of milk. Buffalo's milk is richer than cow's milk. *See* Mammals

Ref.: El-Sokkary and Hassan (1949), *JDR*, **16**, 217 (composition).

BUFFER VALUE (or Buffer Index). This may be described as the resistance of a liquid to changes in pH or hydrogen ion concentration when acid or alkali is added, and is of the greatest importance in dairying, particularly in cheesemaking.

If x mols of acid or alkali are added to 1 litre of a liquid at pH_1, and alter it to pH_2, then the buffer index is : $\frac{x}{pH_1 - pH_2}$ or $\frac{x}{pH_2 - pH_1}$. Thus the less the change in pH the higher the buffer value. It is necessary to define the pH at which the buffer value is measured. For example, for milk it may be 0·024 at pH 6 and 0·018 at pH 6·6.

The buffer effect of milk at pH 8·5 to 9·0 is chiefly due to protein ; at pH 5 chiefly due to phosphate.

Buffering is due to the non-dissociation of weak acids (protein, phosphate, etc., in milk), and the fundamental formula is : $pH = pK + \log \frac{[\text{salt}]}{[\text{acid}]}$, which shows that a weak acid exerts its maximum buffering effect when it is half neutralised and the pH of the solution is equal to its pK (negative logarithm of the dissociation constant). *See* Acidity of milk; Hydrogen ion concentration.

BUFFLOVAK DRIER. A vacuum roller-drier with a single steam-heated roller. It is operated by allowing milk in a pan beneath the roller to form a film which is removed by knives in the usual way. A double receptacle is used to allow emptying without breaking the vacuum. *See* Milk powder.

Ref.: Hunziker (*MP*).

BUILDINGS. *See* Dairies, design of; Dairy farm buildings.

Refs.: Wooley (1954), *Planning Farm Buildings*, London ; Gunn (1952), *Farm Buildings, New and Adapted*, London ; Min. Agric. (1945), *Farm Buildings*, H.M.S.O. ; Billington (1952), *Thermal Properties of Buildings*.

BULGARIAN SOUR MILK. *See* Bulgaricus milk.

BULGARICUS MILK (Yoghurt or Matzoon). This was the original sour milk culture popularised by Metchnikoff and consists of *L. bulgaricus* in milk. *See* Acidophilus milk ; Lactic acid bacteria ; Yoghurt.

Ref.: Burke.

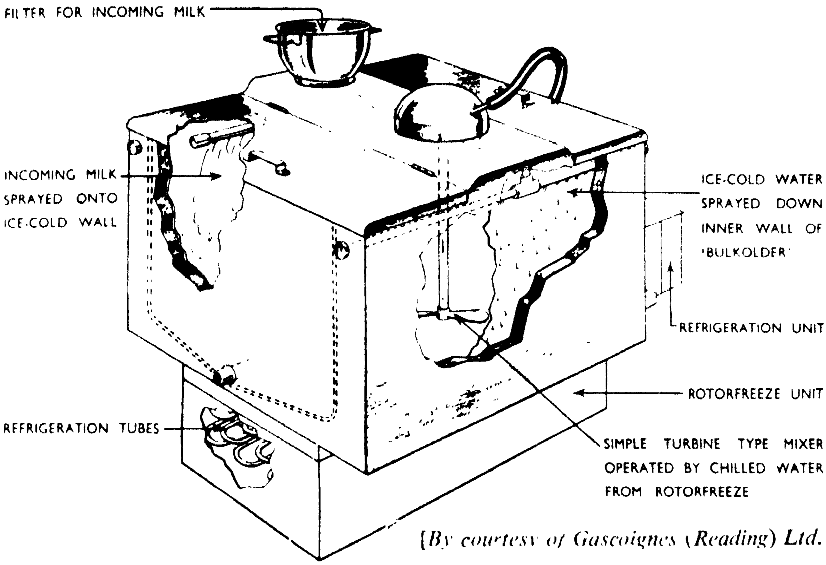
BULK FARM COLLECTION. A system of collection now being developed in U.S.A. in which the milk is usually stored at the farm in an insulated tank at low temperature (Figs. Bk 1 and2) and then pumped direct into the buyer's road tanker. The system eliminates the necessity for cans and their handling and cleaning, and so is an important contribution to the reduction of costs of collection. It is dependent on a high hygienic standard of milk production and requires immediate and efficient cooling of milk on the farm. A small proportion of badly-produced milk may result in keeping quality troubles later in the bulk, even if the bad milk has been rapidly cooled and so has passed the usual dye-reduction tests (*see* Bacteriological grading; Clean milk production; Quality payment; Stability).

Disadvantages of the system in the U.K. are (i) absence of an instantaneous rejection test, (ii) variety of milks (*e.g.* Channel Islands, T.T., South Devon), and (iii) long narrow lanes. The system is now (1953) being tried on an experimental basis in the U.K. In the U.S.A. about 5 per cent. of dairies are using it and about 40 per cent. are considering it as a possibility. However, farm loads are often considerably larger than in the U.K.

Refs.: Anon. (1953), *D*, **70**, 433; Anon. (1953), *AMR*, **15**, 10; Sanders (1953), *MD*, **42**, (11) 38; Matthews (1953), *DI*, **18**, 886.

BULK MILK. (i) Herd bulks are of the order of 20 gal. (one meal) or 40 gal. (both meals), (ii) the smallest tanker size is usually 1000 gal, but 3000 gal. tankers are now common.

BULL. The choice of sire is of the greatest importance not only on account of general health and conformation, but also on account of the effect of the sire on the fat content of his daughter's milk. *See* Breeding.


FILTER FOR INCOMING MILK
INCOMING MILK SPRAYED ONTO ICE-COLD WALL
ICE-COLD WATER SPRAYED DOWN INNER WALL OF 'BULKOLDER'
REFRIGERATION UNIT
ROTORFREEZE UNIT
REFRIGERATION TUBES
SIMPLE TURBINE TYPE MIXER OPERATED BY CHILLED WATER FROM ROTORFREEZE

[*By courtesy of Gascoignes* (*Reading*) *Ltd.*

SECTION VIEW OF 'BULKOLDER' IN OPERATING POSITION ON ROTORFREEZE

FIG. Bk 1.

BULL-DOG, BULL HOLDER. A steel clip which fits in the nostrils of a bull.

BULLER. A cow which is difficult to get in calf and which annoys other cows.

BULLING HEIFER. A heifer which is the right age and size for being served.

BULLOCK. A castrated bull.

BURNT TASTE. A characteristic taint which may be caused by overheating or, in some countries, by intense sunlight. *See* Flavours.

BURRI SMEAR METHOD. This is essentially a simple, cheap, and quick form of the plate count. A loop standardised to contain 0·001 ml. milk is used to withdraw vertically this amount from the sample and to smear it over the surface of two well-dried slopes of yeastrel (or milk) agar in succession. After incubation at 37° C. for two days the number of colonies is counted with a lens. *See* Plate count of milk.

Refs.: Chalmers; Hammer; Todoroff (1947), *M*, **2**, 377.

BUSHEL. The volume of 80 lb. of distilled water at 62° F. *See* Weights and measures.

BUTTER. Analysis and Composition. Variations in the composition of butter are due to differences in manufacture, particularly in the amount of " working ". In England butter must not contain more than 16 per cent. water; consequently the skilled butter maker aims at a moisture content of just under 16 per cent. There is usually about 1 per cent. protein, 0·4 per cent. lactose, 0·15 per cent. ash, and, of course, a variable amount of salt in butter.

For methods of analysis, *see* Richmond.

Colour. The natural colour of butter is due to carotene and other similar fat soluble pigments in the fat globules of the milk, and the yellower the milk the deeper the colour of the butter, so that Jersey and Guernsey milk give a deeper-coloured butter than other breeds. Foods rich in carotene such as grass and green vegetables are best; cereals and artificials result in poor-coloured butter. Butter is therefore much paler in winter. The colour of the butter also falls off as the cow passes through its lactation.

The natural colour may be bleached by over-churning or working, excessive washing, and a wrong churning temperature. The physical condition of the fat-water system also affects colour.

For artificially colouring butter, annatto (*q.v.*) is used.

Cultures. The flavour of butter is produced by the fermentation of bacteria in the cream. Natural souring gives a full flavour, but the use of butter cultures or starters permits a better control of flavour and avoids the danger of undesirable taints. The pasteurisation of cream and the use of selected cultures were developed in 1890-1900, but the nature of the aroma substances was not proved until about 1930.

Cultures of *Str. cremoris* were in general use for some time before the proper significance of associated organisms was realised. For example, margarine manufacturers allowed the culture to " ripen " in order to get the fullest flavour. It was finally shown that the finest flavour was due to the growth of the delicate, slow-growing *Str. paracitrovorus* (*dextranicus*) and *Str. citrovorus*, and that these were encouraged by the addition of citric acid to the milk. The general bacteriological picture, then, is that the vigorous *Str. lactis* and *cremoris* produce acid and so prepare the right conditions for the slow-growing aroma types.

Recently a vigorous, powerful aroma producer, *Str. diaceti-lactis*, has been suggested for butter cultures. (*See* Lactic acid bacteria.)

Faults.

Common faults in butter are:

(1) *Excessive moisture* caused by failing to cool the cream, over-churning, washing with water at too high a temperature, and insufficient working.

(2) *Streakiness* caused by uneven ripening of the cream, overworking, uneven salting, using bad-quality salt, and bleaching effects by sunlight.

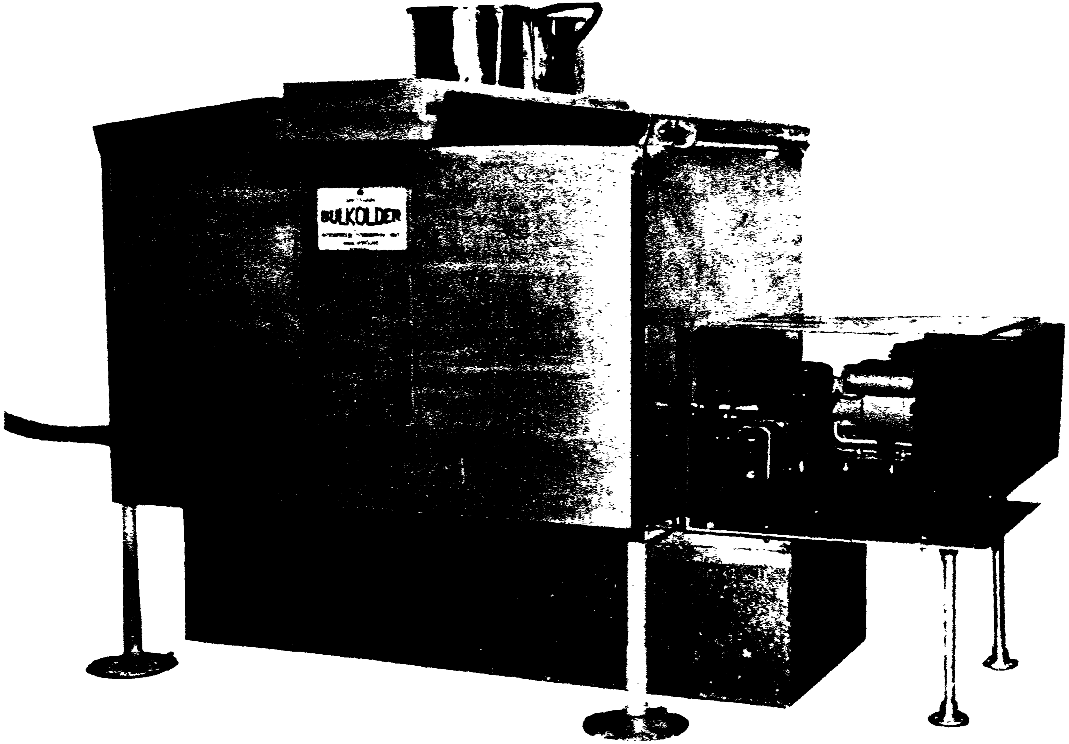
(3) *Greasiness* caused by failing to cool the cream, using fresh unripened cream, churning at too high a temperature, washing with water at too high a temperature, overworking, and use of too high temperatures generally.

(4) *Taints* caused by cows feeding on certain weeds, etc., unhygienic conditions, contaminated water and salt, etc.

(5) *Rancidity* caused by the milk being rich in lipase, overchurning, contamination by copper, etc. *See* also *Sleepy Cream* below.

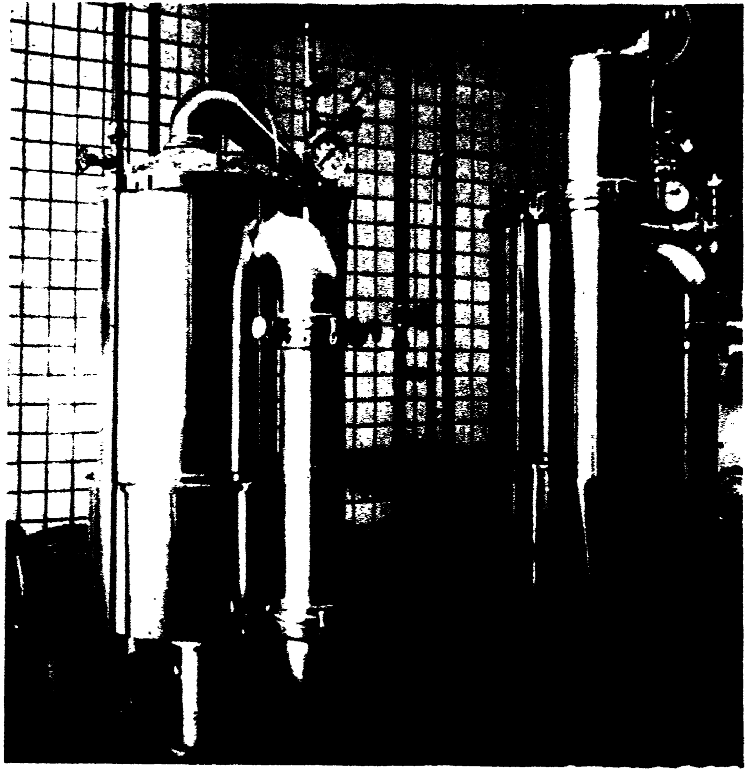
Grading. The following aspects should be considered: flavour (smell and taste); body (firmness); texture (appearance and type of fracture); freedom from moisture; uniformity and correctness of colour; general appearance.

BUTTERMAKING, FARMHOUSE. The main aspects of good butter-making are: (1) a suitable milk (or cream) supply; (2) attention to detail in manufacture; (3) careful storage and packing. Farmhouse and factory or creamery butter-making are of course very different propositions, although the fundamental points are the same in both. Milk is separated and the cream churned until the emulsion " breaks ", *i.e.* the fat in water emulsion becomes a water in fat emulsion. Ripening (*i.e.* souring) of the cream greatly assists churning, but ripened cream butter does not possess the long keeping qualities of sweet cream butter, as acidity accelerates metal-catalysed oxidative faults. The question of the degree of ripening is therefore entirely a question of the market—a quick local sale permits the manufacture of a rich-flavoured butter, ripening giving flavour, while if a long keeping quality, *e.g.* for export, is essential, an unripened pasteurised cream must be used.



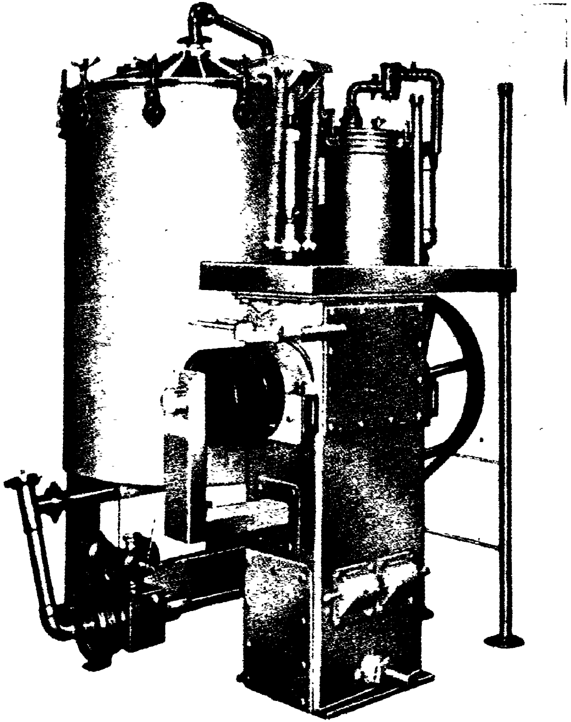
[By courtesy of Gascoignes (Reading) Ltd.

FIG. BK 2.—*Farm Bulk Milk Holder showing Refrigeration Equipment.*



[*By courtesy of Clarke-Built Ltd*

FIG. Bu 1.—*Standard Vacreator Unit.*



[*By courtesy of James Bell Ltd*

FIG. Bu 3.—*The Volatiliser.*

If sweet cream is used, churning temperatures should be lower, otherwise a soft body is obtained. There is always more loss of fat in the buttermilk.

Cream may be ripened naturally or by the addition of starters (*see Cultures* above). Natural ripening requires 2 to 4 days at 60° to 70° F. During this time the cream should be frequently stirred, as otherwise the growth of undesirable bacteria may lead to rancidity and bitterness, and separation of the casein may lead to discoloration in the final product.

A natural starter, *i.e.* buttermilk from a previous churning, is sometimes used.

To get the best results from a starter, the cream should be pasteurised at 160° F. for about 15 min. as soon as separated. In factory practice cream is often heated to 200° F. and even subjected to a vacuum process to remove undesirable odours. After cooling to about 60° F. about 2 per cent. starter should be added—more in winter and less in summer. It is essential to stir the cream at intervals until the desired acidity is attained.

Churning. The churn, butter worker (or drier), pails, sieve, Scotch hands and prints, rinsing bowl, scoop, and cloths must be thoroughly cleansed and scalded before use, and kept wet with cold water until used.

Cold water is first added to the cream as this facilitates churning. In winter a temperature of 58° to 62° F. and in summer a temperature of 54° to 58° F. should be used. After straining, the cream is churned slowly at first, the air being released frequently. When air no longer exudes the rate is increased, and after 15 to 20 min. small grains should appear. When this occurs, a little water at about 3° F. lower than the churning temperature is added to prevent the formation of lumps. Churning is then continued until the required size of grain is reached. The buttermilk is then drawn off through a sieve, and wash water at about 6° F. lower than the churning temperature added. Washing is continued until the washings come out clear.

The butter is now removed with the scoop and spread over the worker. Salt (usually ¼ to ¾ oz. per lb. of butter) is sprinkled over the butter, and the latter worked into a solid mass free from moisture by rolling it repeatedly. When finally worked so that no moisture exudes when pressed between the Scotch hands, it is weighed and made up into the required shapes or packed into boxes. Salt improves flavour and keeping quality and also assists in the removal of buttermilk. The presence of magnesium or calcium salts leads to bitterness and absorption of moisture from the atmosphere.

"Sleepy Cream." This is one of the commonest faults or troubles in buttermaking, but is rare with properly ripened cream.

The causes may be classified as follows: (i) Chemical abnormalities in the milk : (*a*) mastitis ; (*b*) late lactation (in such cases the milk is alkaline—which retards churning—and the fat globules sometimes small) ; (*c*) effect of feeding—pasture peculiarities, excessive feeding of roots or manuring with bone fertiliser. (ii) Insufficient concussion in the churn : (*d*) frothing in cream due to gas formation and neglect to ventilate ; (*e*) overfilling the churn ; (*f*) too thick cream. (iii) Bad technique : (*g*) churning at too low a temperature ; (*h*) churning too quickly at first ; (*i*) accidental presence of soda or soap.

Yield. ***Calculating yield of butter.*** W lb. of cream of F per cent. fat will give the following yield of butter of M per cent. moisture content : $\frac{FW}{100 - M}$ lb.

Butter overrun. The theoretical butter overrun from a cream of a fat content of F per cent. and butter of moisture content of M per cent. is $\frac{100\ M}{100 - M}$ per cent. ; the weight of overrun of butter from W lb. of cream is $\frac{WFM}{100(100 - M)}$ lb.

Buttermilk. This is the term applied to that liquid which separates when cream changes into butter (*see* Composition, average, etc.). In butter factories it is sometimes added to separated milk and dried.

Butter ratio. The following formula gives the lb. butter obtainable from 100 lb. milk :

$$\frac{(\text{Per cent. fat in milk} - \text{per cent. loss in separating and churning}) \times 100}{\text{Per cent. fat in butter}}$$

e.g. for 4·2 per cent. fat milk and 0·2 per cent. loss and 84 per cent. fat in butter

$$\text{yield} = \frac{(4{\cdot}2 - 0{\cdot}2) \times 100}{84} = 4{\cdot}76.$$

$$\therefore \text{ butter ratio} \qquad = 1 : \frac{100}{4{\cdot}76} = 1 : 21.$$ *See Standardisation* below.

BUTTERMAKING, FACTORY. Buying Milk and Cream. ***Introduction.*** Whether milk or cream is accepted at a factory, payment of differential prices according to quality is of the utmost importance for maintaining and raising the quality of the butter produced. In many countries the payment of prescribed differentials in price according to grade is compulsory for milk and/or cream intended for manufacturing purposes, and employees responsible for this work must possess certificates of competency.

Grading. (*a*) *Milk.* In the case of milk, palate grading is usually supplemented by such tests as the methylene blue, resazurin, sediment and fermentation tests.

(*b*) *Cream.* Owing to the complexity of the factors affecting quality, the only practical method of grading cream is on the basis of *sight*, *smell*, and *taste*. The routine procedure by which these three senses are brought into play is as follows: The grader first carefully sums up the external appearance of the can containing the cream as it approaches him on a roller conveyor system. Dents, rust or dirt are presumptive evidence of want of care in forwarding the cream. The lid is then removed and the senses of sight and smell brought into play, the smell being noted as soon as the lid is lifted. A choice grade cream will possess a clean aroma free from any " off " odour. The cream is next well mixed and, after a sample has been taken for a butterfat test, a small quantity is removed from the can on a glass rod or bone spatula to determine the body and texture. A choice quality cream has a smooth, even consistency. Finally the cream should be tasted ; the taste should be clean, either sweet or of a pleasant acid taste (depending on whether a " sweet " or " sour " cream is being graded) and free from any " off " flavour.

After being graded, the cream is passed along the conveyor to a set of platform scales where the weight is recorded. The particulars concerning weight and grade entered in the platform book are later recorded in the general office. The cream is then tipped into the cream receiving vats which correspond with the cream grades. The empty can travels to a rotary or straight-through type can washer, and thence to the can storage verandah or back to the cream or milk truck.

Method of payment. Milk and/or cream for manufacture into butter are commonly purchased on the basis of either (1) the butterfat content ; or (2) the estimated quantity of commercial butter which they will yield. In countries which use the commercial butter system a ready reckoner, *Manufacturers' Butter Computing Tables*, is used to show at a glance the quantity of commercial butter which should be made from any given weight of cream testing between 29 and 50 per cent. butterfat.

In European dairy factories the butterfat in milk and cream is determined by the Gerber method, whereas in U.S.A., Canada, New Zealand, and Australia, the Babcock test is almost universally adopted in factory practice. In countries where cream is not delivered daily to the factories, the butterfat test is usually carried out on each delivery of cream. In countries where whole milk or sweet cream is supplied daily to factories, a sample of each individual farmer's milk or cream is taken daily, placed in a composite sample bottle and the butterfat determined on a composite sample every seventh or tenth day. Composite samples are thus taken in order to determine in one test the amount of fat in the milk or cream for a definite period and thereby save considerable expense and time.

Neutralisation. Wholemilk or fresh cream received by factories for buttermaking can be pasteurised without any other treatment. Unless cream is delivered daily the acidity is seldom less than 0·25 per cent., the actual percentage depending on conditions of production, storage and frequency of delivery. Unless the acidity is reduced such cream might curdle on heating, and the resultant butter will be of inferior keeping quality and flavour (Hunziker (B), Totman *et al.*).

The process by which the acidity is reduced to the desired degree by means of alkaline compounds, such as sodium bicarbonate, sodium sesquicarbonate modified sodas and lime, is known as *neutralisation.*

Objects. The objects of neutralisation are to reduce the acidity in cream to a point which permits pasteurisation without risk of curdling, to produce butter which keeps well in cold storage, to avoid fat losses due to the coagulation of the casein on heating, to reduce undesirable flavours resulting from the heating of acid cream and to assist in the removal of volatile odours.

For maximum keeping quality of butter which is required to withstand prolonged cold storage, such as New Zealand and Australian, the *p*H of the butter serum should fall within the range *p*H 6·8 to 7·2. (McDowell 1937, 1938, Gilmour and Arup 1935, Kretchmar 1940, Loftus Hills, Scharp and Bellair 1934). To achieve this the residual acidity in the cream after neutralisation is adjusted to 0·8 to 0·10 per cent. calculated as lactic acid, in cream containing 34 to 37 per cent. butterfat.

Factors affecting neutralisation. Efficient neutralisation depends upon:

1. Accurate sampling of cream for the acidity test.
2. Accurate testing for acidity.
3. Accurate estimation of the amount of cream to be neutralised. (The neutralising vat should be calibrated or provided with a marked dip-stick to show the gallonage of cream.)
4. Careful weighing of the calculated quantity of the chosen neutraliser.
5. Thorough mixing of the neutraliser through the cream prior to pasteurisation.
6. Careful check-testing of the neutralised and pasteurised cream.

Neutralising compounds. *Sodium bicarbonate* ($NaHCO_3$) is a cheap and efficient neutraliser. The large quantity of CO_2 liberated during neutralisation is a disadvantage where vacuum pasteurising systems are employed. One part of lactic acid is neutralised by 0·933 part $NaHCO_3$.

Sodium sesquicarbonate ($NaHCO_3$, Na_2CO_3, $2H_2O$) is found naturally as the mineral *Trona* and is also manufactured commercially. An equivalent weight evolves two-thirds as much CO_2 as sodium bicarbonate. One part of lactic acid is neutralised by 0·837 part of sodium sesquicarbonate.

Modified sodas are mixtures of sodium bicarbonate and sodium carbonate sold either as mechanical mixtures or crystalline compounds of bicarbonate and carbonate. Due to their sodium carbonate content, care is necessary to avoid over-neutralisation and saponification of fat. Less frothing of the neutralised cream during pasteurisation occurs, as less CO_2 is liberated than by sodium bicarbonate. The alkalinity varies with the different compounds; hence special neutralising charts or instructions are supplied by the manufacturers.

Calculating neutraliser required. The quantity of neutraliser needed to reduce the acidity of cream is calculated as follows:

1. Find the required reduction in acidity by subtracting the desired acidity from the actual percentage acidity in the raw cream.
2. Calculate the weight of lactic acid to be neutralised by multiplying the weight of cream by the percentage of acid reduction required and dividing by 100.
3. Calculate the amount of neutraliser by multiplying the weight of lactic acid to be neutralised by the parts of neutraliser necessary to neutralise one part of lactic acid.

Example. How much sodium bicarbonate is needed to reduce the acidity of 3000 lb. cream from 0·32 to 0·10 per cent. ?

1. Acidity reduction required $= 0{\cdot}32 - 0{\cdot}10$ $= 0{\cdot}22$ per cent.
2. Weight of lactic acid to be neutralised $= \dfrac{3000 \times 0{\cdot}22}{100}$ $= 6{\cdot}6$ lb.
3. Weight of sodium bicarbonate required $= 6{\cdot}6 \times 0{\cdot}933$
   (1 part lactic acid is neutralised by 0·933 part $NaHCO_3$) $= 6{\cdot}16$ lb. or 6 lb. 3 oz.

In practice the last two stages are combined into one equation:

$$\begin{array}{c}\text{Weight of}\\ \text{neutraliser}\\ \text{required (lb.)}\end{array} = \frac{\begin{array}{c}\text{Acidity}\\ \text{reduction}\\ \text{required}\end{array} \times \begin{array}{c}\text{Weight}\\ \text{of cream}\\ \text{(lb.)}\end{array} \times \begin{array}{c}\text{Parts of neutraliser}\\ \text{needed per 1 part}\\ \text{lactic acid}\end{array}}{100}$$

The equation for the previous example thus becomes

$$\text{Sodium bicarbonate needed} = \frac{0{\cdot}22 \times 3000 \times 0{\cdot}933}{100} = 6{\cdot}16 \text{ lb.}$$

The weighed neutraliser is dissolved in water at the rate of 1 lb. to 1 gal. and added to the cream. It must not be dumped bodily into the cream but sprayed in by means of a steam injector or pump, or gravitated from a mixing vessel placed on a higher level than the neutralising vat. The cream, which should be at a temperature of about 90° F., is kept constantly agitated during the addition of the neutraliser and for at least a further 15 min.

Standardisation. The fat content of the cream is standardised to the desired percentage for churning by adding the appropriate quantity of water during neutralisation. By knowing the fat content of the cream and the quantity let into the churn, the number of boxes of butter in the churning can be estimated with some accuracy, and this assists in controlling the moisture and salt content of the butter.

Pasteurisation in the butter industry. Many countries legally enforce pasteurisation of all milk and cream for butter manufacture. The objects of pasteurisation in the butter industry are to destroy pathogenic bacteria; to reduce the miscellaneous microbial flora to low numbers; to enhance the keeping quality of butter; to eliminate or reduce feed flavours, and to produce butter of uniform flavour.

The efficiency of pasteurisation depends on the bacterial flora of the raw milk or cream, the temperature employed, the hygienic condition of factory equipment, and the operation of the pasteuriser.

Systems of pasteurisation. (1) *Batch pasteurisation* is a satisfactory and economical method for small factories, but is not practicable for larger factories. The cream is heated to 145° F. for 30 min., although higher temperatures, with a corresponding reduction in time of exposure, are permissible in the butter industry.

(2) *Flash pasteurisation* may be subdivided into (*a*) direct flash, and (*b*) regenerative systems. A continuous stream of milk or cream, kept flowing at a uniform speed through the machine, is heated almost instantaneously to at least 180° F.

The direct flash system is much less used than the regenerative system. The pasteuriser consists of a closed, hollow drum, equipped with a revolving agitator. The drum is jacketed with a steam or water compartment through which live steam or boiling water is circulated. The revolving agitator forces the cream against the side of the internal drum through which heat is transferred from the steam or boiling water. A vacuum deodoriser is often used in conjunction with the direct flash pasteuriser. The cream is diverted from the pasteuriser into the deodoriser, operated under a vacuum, which causes the removal of odours and gases.

The cream is cooled by passing it over an ordinary tubular surface, or through a plate-type cooler.

Regenerative flash pasteurisers are of several types, Dome and Plate.

The Dome type pasteuriser consists of two metallic domes, between which is fitted a revolving agitator. Steam within the inner dome is the heating medium. For operation the revolving agitator is first set in motion, water pumped between the domes, the steam turned on, and the water heated to the pasteurising temperature, usually 185° F. When the desired temperature is attained, the tap of the cream-neutralising or holding vat is turned on, the water turned off, and the cream pumped into the pasteuriser. After heating, the cream is pumped over a surface, or through a plate-type cooler.

Two regenerative pasteurisers are often used in tandem in order to facilitate temperature control and minimise scorching of the cream.

The Eclipse pasteuriser consists of steam-heated rollers and coils. The cool ingoing cream passes through the coils on to the rollers where it is heated and flows over the outside of the coil. This machine is not widely used.

Although increasing in popularity for pasteurising milk for the market milk industry, plate-type pasteurisers are not extensively used for pasteurising cream for butter manufacture.

(3) *Vacuum pasteurisation.* The pasteurisation of cream by systems utilising the principle of reduced atmospheric pressure has advanced rapidly in recent years; in some countries this method is displacing all others. Machines which employ this principle are known as the vacreator and the volatiliser.

The *Vacreator* (Hammer 1941) (Fig. Bu 1) developed in New Zealand, is now also widely used in butter factories in Australia, U.S.A., and other countries. The machine consists essentially of a series of stainless steel chambers through which cream is passed during pasteurisation. The capacity of the machines varies from 250 to 1500 gal. per hr. The flow cycle is illustrated in Fig. Bu 2. The cream, delivered by the feed pump X, is admitted by the float control valve to a perforated spray pan located in the first, or pasteurising, chamber A. In dropping through the spray pan the cream is divided into numerous droplets (30,000 per lb.) which are heated by direct contact with steam admitted through valve B. The pasteurising section is operated under a reduced atmospheric pressure, usually between 6 and 11 in., which results in a temperature varying from 200° F. to 190° F. The amount of steam passed through valve B is in excess of that needed to heat the cream to the pasteurising temperature. This assists in the removal of volatile substances imparted to the cream by feeds and weeds eaten by the cows. In the bottom of the pasteurising chamber is located a spring-actuated equilibrium valve C. The second chamber E and the pipe D are kept at a reduced pressure of 15 to 18 in. by an ejector condenser F. The relative pressures in A and E are adjusted by tension on the equilibrium valve C.

From the pasteurising section A the cream is drawn past the equilibrium valve C, up the pipe D and discharged tangentially into chamber E. At the

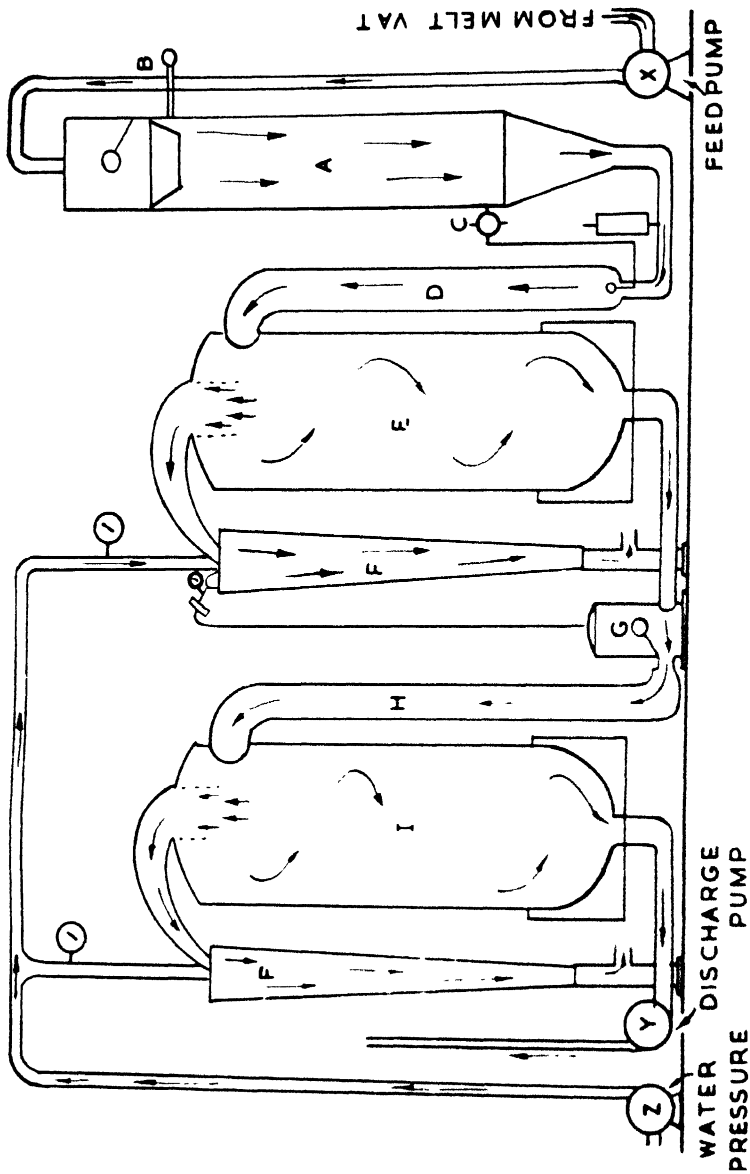
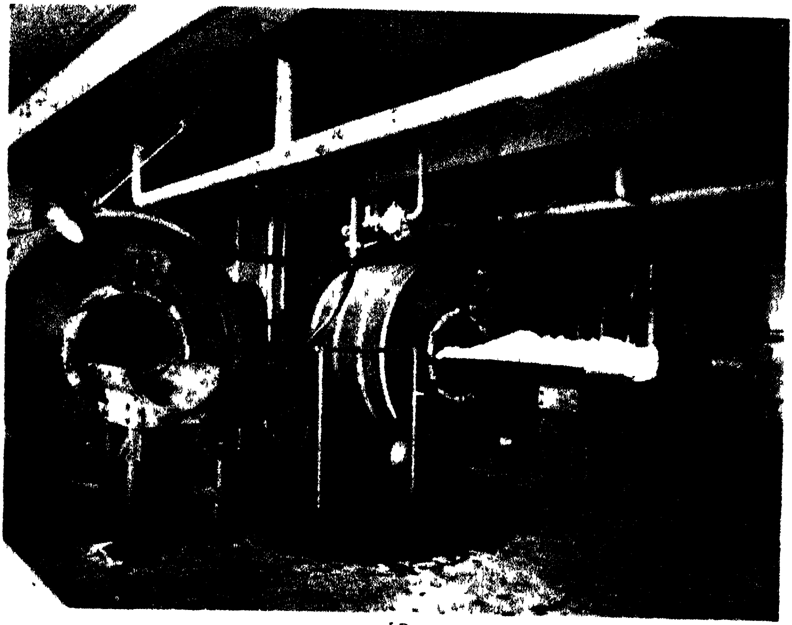
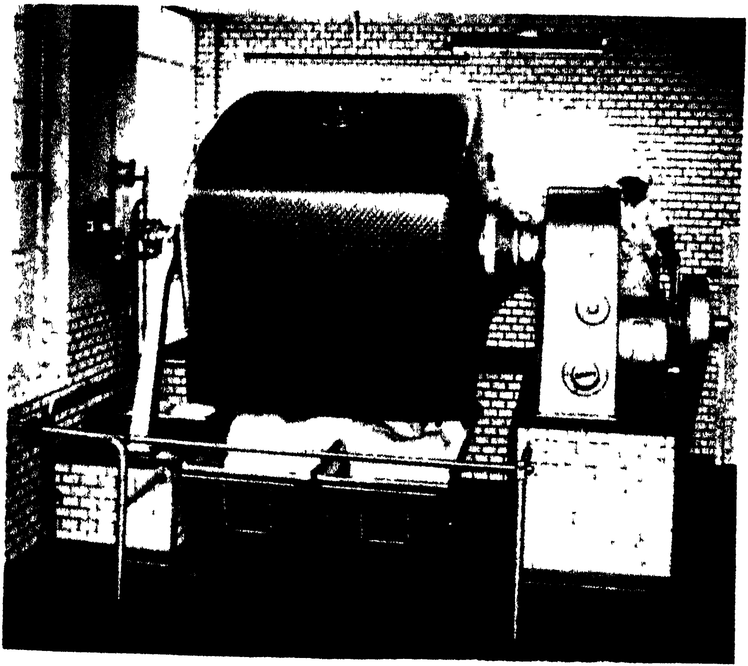


FIG. Bu 2 – *Diagram illustrating flow cycle of the Vacreator (Hammer, 1947).*



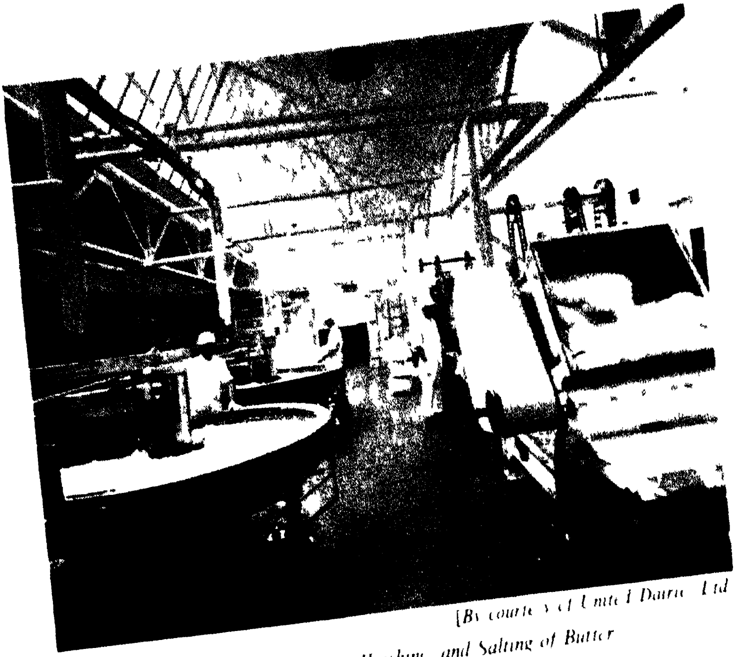
[*By courtesy of the Milk Marketing Board.*

FIG. Bu 4.—*Factory Churn Worker.*



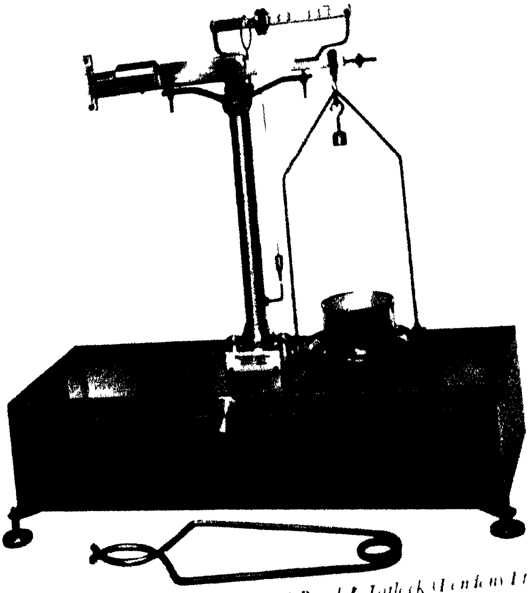
[*By courtesy of Hiron & Rempler Ltd*

FIG. Bu 5.—*Stainless Steel Roller-less Churn and Butter Worker. Butter Ejected into Trolleys*



[By courtesy of United Dairies Ltd

FIG. Bu 6.—*Working, Washing and Salting of Butter*



[By courtesy of Baird & Tatlock (London) Ltd

FIG. Bu 7. *Balance with Attached Rider for Moisture Determination* reduced pressure of 15 to 18 lb. in this chamber the cream boils at 160° to 180° F. and releases water vapour which carries off with it volatile gases. The intermediate float valve G controls the flow of cream through pipe H into a third chamber I, maintained at a still higher vacuum, usually 27 to 28 in. More water vapour and volatile substances are removed and the cream cooled to about 110° F. in this chamber. The cream is then pumped from this chamber to the cooler by a multi-stage centrifugal pump Y. The rise in temperature of the cold water, forced through the ejector-condenser by pump Z, is an indication of the amount of water vapour drawn off from the hot cream in the reduced pressure chamber.

The vacreator is very efficient in removing feed and some weed taints and bacterial taints from cream (Riddet *et al.*, 1940) and in destroying the microbial flora.

The *volatiliser* (Hunziker (B) (Fig. Bu 3) consists of a steam injection flash pasteuriser and a high-vacuum retort (vacuum pan). The pasteuriser is constructed of stainless steel. The cream enters the pasteuriser at the top where it intermingles with jets of direct steam. As it flows over a series of stainless steel plates in a thin film, the cream is heated progressively, under steam pressure, to a uniform temperature of 185° F. or higher. The discharge from the pasteuriser is regulated by a float-controlled valve, thus maintaining the desired steam pressure while a high vacuum is existing in the volatilising chamber.

The vacuum pan is constructed of glass-coated steel. It is equipped with a rotating header of multiple, tangential cream-distributing tubes, a condenser with wet vacuum pump capable of maintaining a 27 to 28 in. vacuum, and a positive centrifugal cream discharge pump. The cream from the pasteuriser enters the vacuum pan at the top through the cream discharge tubes. Its release into the high vacuum pan causes it to form a fine mist which impinges against the sides of the pan and flows down over the glass-coated surface in a thin film. The escaping vapours and volatilised products are voided through the condenser, and the high vacuum (27 to 28 in.) lowers the temperature of the cream to approximately 101 F. The treated cream discharges from the vacuum pan at the bottom by means of a special, positive-action centrifugal pump.

The Cooling and Holding of Pasteurised Cream. ***Cooling cream.*** Batch and Plate pasteurisers are designed to enable both heating and cooling to be carried out in the same unit, but other pasteurisers require an independent means of cooling the cream. The coolers used for this purpose are of either the tubular surface or plate types.

(*a*) *Surface coolers* are usually constructed of stainless steel or tinned copper. A cream spreader-tray is set above the cooler to distribute the cream evenly on each side of the coils. Ordinary mains water is pumped through the uppermost section, chilled brine through the middle section, and direct expansion ammonia cooling is used for the bottom section. The cooler is often in two independent sections—the first using atmospheric water and the second chilled brine. In this case an extra pump is necessary to pump the cream from the bottom tray of the first section to the top spreader-tray of the second section. Surface coolers take up a good deal of space, are relatively difficult to clean and offer some risk of post-pasteurisation contamination of the cream.

(*b*) *Plate coolers.* The plate coolers differ only from the plate pasteurisers in that a cooling medium is used instead of a heating agent. They economise in space and, as the cream is completely enclosed, obviate the risk of atmospheric contamination.

Holding cream. From the cooler the cream is pumped into cream-holding vats where, if necessary, it can be further cooled and kept until it is ready for churning. Cream-holding vats may be of either vertical or horizontal type. The vertical vats are glass-lined, and either solidly insulated or brine-jacketed as well as insulated. The solid insulated vats have a revolving agitating-coil vertically set up, through which chilled brine is pumped if further cooling is necessary. The brine-jacketed, insulated vats are fitted with agitating propellors to keep the cream constantly agitated while cooling is in progress, as cooling depends on conduction, through the internal walls of the vat, from the chilled brine in the jacket.

Horizontal vats are of either glass-coated or stainless steel construction internally, and are usually solidly insulated. They are usually fitted with horizontal revolving coils which are used to agitate the cream and through which chilled brine is pumped to cool; brine-jacketed vats with agitators are sometimes used.

All holding vats have insulated lids which should always be closed while cream is pumped into, or stored in them.

The cream is kept in the vats for some hours at a low temperature to allow the fats to crystallise, a necessary procedure to ensure butter of good body and texture.

In countries which produce starter-ripened butter the starter is added to the cream in the vats. The cream is then held for some hours at a temperature permitting the lactic acid bacteria to develop the desired acidity, after which the cream is cooled to and maintained at churning temperature until churning begins.

Churning. ***Theories of churning.*** Several theories have been advanced to explain the phenomenon of churning. The more acceptable of these are (i) *phase-inversion* and (ii) the *foam* theories. Fischer and Hooker (1917) believe the conversion of cream into butter represents a change from an oil-in-water emulsion to a water-in-oil system. Rahn (1922) claims there is at first a close packing of the fat globules in the foam and the protein gradually assumes a solid character. Continued agitation causes the foam to collapse and the fat globules then to coalesce. Clayton considers the latter theory to be the more probable.

Churnability of cream. The churnability of cream is conditioned by:

1. *Churning temperature.* This is governed by the melting point of the butterfat and atmospheric temperature. With softer fats a lower churning temperature is needed and vice versa. The melting point of the butterfat depends on:

(*a*) *Season of the year.* Fresh, green pastures increase the proportion of softer (lower melting point) glycerides in the milk fat; as pastures dry off the harder (higher melting point) fats predominate. Atmospheric temperature must be allowed for in determining the churning temperature. Churning temperatures must be lower in the summer to prevent too high a rise in the temperature of the cream during churning which would cause the butter to become greasy during working.

(*b*) *Stage of lactation.* As the lactation period of the cow advances, the melting point of the milk fat increases.

(*c*) *Food.* The effect of pastures was mentioned in (*a*). Dry, hard foods like hay and chaff produce hard fats; succulent foods and most concentrates tend to give soft fats. However, cottonseed meal raises the melting point of the milk fat.

(*d*) *Breed of cow.* Dairy cattle—the milk of which contains large fat globules—such as the Jersey and Guernsey breeds, produce milk with a higher proportion of softer fats. Conversely, breeds which yield milk containing small fat globules are noted for the higher melting points of the milk fat. Cream which contains larger fat globules also churns more readily.

The churning temperature should be adjusted to enable the butter to " break " in 30 to 40 min. Too high a temperature causes the cream to churn too quickly in soft lumps which drain poorly, butterfat losses in the buttermilk are increased, the texture of the butter is prone to become greasy and there is risk of the butter containing excess moisture. Too low a temperature prolongs churning, makes working difficult, and gives butter of too firm a texture for easy incorporation of salt and moisture.

2. *Butterfat content of cream.* Minimum loss of butterfat occurs in the buttermilk if cream for churning contains 37 per cent. butterfat; while to keep losses low, the fat content at churning should not be below 34 per cent. The time of churning is also prolonged if the fat content of the cream is too low.

Owing to the dilution of the cream by the condensation of steam during vacreation, the quantity of water used to dissolve the neutraliser and for rinsings should be kept to a minimum during operations in any factory equipped with a vacreator.

3. *Acidity of cream.* Acid cream churns more readily than sweet cream. However, the practical considerations mentioned in connection with neutralisation of cream preclude the churning of acid cream if the butter is to be cold-stored.

4. *Amount of cream in churn.* Maximum agitation and most rapid churning occur when the churn is about one-third full of cream. If the churn is too full (over two-thirds capacity) maximum agitation is not attained and churning may be prolonged. A very small quantity of cream in a churn may also escape proper agitation. The usual factory practice is to fill churns within 2 to 4 in. of the half-full mark.

5. *Nature of agitation.* During churning the agitation of the cream is governed by the size and type of churn, the revolutions per min. of the churn, and the amount of cream in the churn. The churn should therefore be operated at the speed prescribed by the manufacturer.

6. *Pre-churning holding period.* Cream after pasteurisation must be kept for some hours at a low enough temperature to permit of the crystallisation of the butterfat. If churned too soon after pasteurisation the butter is prone to be soft and of inferior texture, and fat loss in the buttermilk is relatively high. The cream is preferably held overnight before churning, but if this is not practicable it should be cooled to 2° F. below the normal churning temperature and held for at least 3 hr.

Churning procedure. Butter churns may be constructed of wood or metal. Wooden churns (Fig. Bu 4) are usually fitted with internal rollers to enable the working of the butter in the churn. In U.S.A., rollerless wooden churns having wood vanes to accomplish the working of the butter are used. Metal churns are without rollers, the working of the butter being effected entirely by concussion (Fig. Bu 5).

Before use, the churn is treated with boiling water, followed by cooling with very cold water to prevent butter adhering to the woodwork. Some factories prepare the churn simply by using cold water containing 200 p.p.m. chlorine.

The cream in the holding vat is also agitated, and the temperature checked and adjusted, if necessary, before letting it into the churn. A sample is also taken for acidity and butterfat tests. The holding vats should be calibrated, or a graduated dip stick used, in order to enable an estimation to be made of the quantity of butter in the churning; this facilitates control of the composition of the butter. The usual practice is to fill the churn with cream within 2 to 4 in. of half full. The degree of filling is important, as the cream swells during churning and may completely fill the churn, thus preventing concussion if too much cream was present initially.

When the cream has been run into the churn it is revolved in top gear. Modern churns are usually fitted with a device to allow gases to escape, but if not, the vent holes are opened after a few revolutions. Concussion causes coalescence of the fat globules at an ever-increasing rate, until a stage is reached where the clumps of fat globules suddenly attain such a size as to become discrete granules.

This sudden change is described as the " break " and its occurrence is shown by a clearing of the sight glass. The churning temperature should be such as will ensure that the " break " occurs within 30 to 40 min. The churn is then sometimes stopped and about 5 per cent. " breakwater ", 4° to 5° F. below churning temperature, added to firm the grain, retard the larger fat globules and enable the smaller to coalesce. However, " breakwater " may not be necessary if the fat content of the cream was standardised. Churning is complete when the butter granules have become wheat grain to pea size. The butter milk is then drawn off through a fine strainer which catches any butter granules escaping from the churn.

Washing the butter. As soon as the buttermilk is drawn off, a small quantity of water at about 5° F. below churning temperature is sprayed over the surface of the butter granules and drained off. The taps of the churn are turned off, enough water added to float the butter, the churn revolved for about ten revolutions, and again drained. The temperature of the wash water in relation to the temperature of churning has a marked effect on the texture and hardness of the resultant butter. The actual difference in temperature is varied at times on this account. Recent work (Pont 1946) tends to indicate that washing may be dispensed with without a significant deterioration in the keeping quality of the butter.

Salting and working. The incorporation of salt, dispersal of the moisture as minute droplets, and compacting of the granules into the familiar form of butter is called *working*. The amount of salt to be incorporated will depend on market requirements. The approximate quantity of butter in the churn and the desired salt percentage being known, the quantity of salt needed can be readily calculated. It is weighed out and distributed evenly over the surface of the butter granules. In the case of wooden churns with internal workers, the churn is closed, set in motion in low gear for 2 to 3 min., after which it is usually stopped, and the brine drained off. (This may be saved in a bucket.) Working is then continued for another 4 to 8 min. when a representative sample of the butter is taken for the primary moisture test. The calculated quantity of water to bring the moisture content to the desired percentage (usually 15·8) is weighed out and added. The brine from churn drainings is often used for this addition. The churn is again closed and worked for a further 3 to 5 min., or longer if necessary, until the butter is of a firm, waxy texture. The moisture content is again determined to ensure that the butter does not exceed the legal maximum percentage.

The times just mentioned may need modification according to the type and size of churn and other factors in individual factories. It is stressed, however, that the churning temperature must be such as to allow for the efficient working of the butter. Independent workers are illustrated in Fig. Bu 6.

Moisture test. A known weight of butter (usually 10 g.) in a weighed metal dish is heated until all water is expelled. After cooling to atmospheric temperature the dish and contents are reweighed and the moisture percentage calculated. The balances used for moisture testing in factories are the physical balance (Fig. Bu 7), torsion balance, one-pan balance and the Avery balance.

Packages and packing. In Australia, New Zealand, and Eire, butter is packed in 56 lb. wooden or fibre-board boxes; in Denmark, wooden casks which contain 110 lb. of butter are used. The butter must be firmly packed in its container which is lined with vegetable parchment. Mechanical packers are now used in large factories, the butter being placed into the hopper from which spiral worms cause it to be extruded through an opening the size of the standard box (Figs. Bu 8 and 9). The extruded butter is cut into blocks, weighed, papered and the box slipped over it; the top surface is then neatly levelled off, the top paper closed over and the lid of the box nailed down.

Factories which sell butter locally usually install butter-packing machines which enable the butter to be packed direct from the churn in ½ lb. or 1 lb.

wraps. A series of papers by Barnicoat (1938, 1945, 1948) describes experiments on the packing and storage of butter.

Losses of Butterfat in Buttermaking. ***Buttermilk losses.*** There is a normal loss in the buttermilk of nearly 1 per cent. of the butterfat purchased in milk and cream; and up to 2 per cent. may be lost if careful control is lacking (Udy 1931, McDowall 1938). The main factors affecting the butterfat loss in buttermilk (Wiley 1939, Lyons and O'Shea 1936, Combs 1928) are:

1. Agitation of hot cream.
2. Dilution of cream with water.
3. Fat content of cream. The minimum loss occurs in the churning of cream containing 37·5 per cent. butterfat.
4. Cooling of cream. Cream should be cooled to a temperature which permits crystallisation of the fats and then held at least 3 hr. prior to churning.
5. Size of fat globules. Small fat globules in cream increase the loss. This accounts for a higher seasonal loss in spring and the higher losses which occur where vacreation of cream is practised.
6. Churning temperature. Cream should be churned at a temperature which allows the buttermilk to be drawn off in about 40 min. High churning temperatures, which cause rapid churning, increase the fat loss.
7. Amount of cream in churn. Overfilling or underfilling the churn increases the loss of fat.

Other losses. Apart from the loss in buttermilk, there is always some fat lost through mechanical causes. The latter losses, which should not exceed 1 per cent. in an efficient factory (Valentine 1932), are accounted for by remnants of cream in cans, rinsings from vats, pumps and pipes, cream used for samples, leakage from pipe unions, spillage and the packing of the butter.

Overrun. ***Definition.*** Milk or cream received at a butter factory is generally paid for on the basis of its butterfat content. As commercial butter contains not only butterfat but also curd and moisture and usually salt, the amount of butter manufactured exceeds the quantity of butterfat purchased. This difference between the butter manufactured and the butterfat purchased is known as the overrun, which is usually expressed as a percentage of the butterfat purchased.

Thus	if butterfat purchased	100,000 lb.	
	and butter manufactured	120,000 lb.	
	the overrun is	20,000 lb.	20 per cent.

Importance. Overrun is of technical and economic importance. It enables the factory manager to check the efficiency of factory operations and to ensure that all the butter legally permissible is made from the butterfat bought. Low overrun suggests high fat losses in the factory, faulty control of the composition of the butter, over-reading of fat tests or incorrect weighing of milk or cream. High overrun, if the control of the composition of the butter is satisfactory, suggests that tests are under-read, or weights of milk or cream are incorrectly recorded. However, a satisfactory overrun does not necessarily imply all is well, as counteracting factors may give a normal overrun even if there is some inefficiency in the factory.

Control. Effective control of overrun depends on (*a*) accurate recording of weights and butterfat tests; (*b*) control of fat losses in handling and churning, and (*c*) control of the composition of the butter.

Allowing an unavoidable loss of 2 per cent. of butterfat during manufacture in a factory which receives cream (3·75 per cent. if milk is received) and taking as an objective butter containing 15·8 per cent. moisture, 1·5 per cent. salt and 0·8 per cent. curd, the overrun which may reasonably be expected can be calculated as follows:

For every 100 lb. fat purchased, 98 lb. is included in the butter. As the water + salt + curd (15·8 + 1·5 + 0·8) = 18·1 per cent. the butter should contain 100 − 18 1 = 81 9 per cent fat Therefore, the amount of butter containing 81 9 per cent fat which can be made from 98 lb fat is.

$$\frac{100}{81\ 9} \times \frac{98}{1} = 119\ 66 \text{ lb.}$$

The overrun is 119 66 − 100 = 19 66 lb, or 19 66 per cent

Overrun obtainable. Valentine (1932) has prepared a table showing the overrun obtainable in accordance with variations in the composition of the butter and manufacturing losses. The following table is adapted from his paper

Composition of butter		*Percentage of manufacturing losses*								
Fat %	*Water salt curd* %	1 75	2 00	2 25	2 50	2 75	3 00	3 25	3 50	3 75
		Percentage of overrun								
81 00	19 00	21 29	20 98	20 67	20 37	20 06	9 75	19 44	19 13	18 82
81 25	18 75	20 92	20 61	20 30	20 00	19 69	19 38	19 07	18 76	18 46
81 50	18 50	20 55	20 34	19 93	19 63	19 32	19 01	18 71	18 40	18 09
81 75	18 25	20 18	19 87	19 57	19 26	18 96	18 65	18 34	18 04	17 73
82 00	18 00	19 81	19 51	19 20	18 90	18 59	18 29	17 98	17 68	17 37
82 25	17 75	19 45	19 14	18 84	18 54	18 23	17 93	17 62	17 32	17 02
82 50	17 50	19 09	18 78	18 48	18 18	17 87	17 57	17 27	16 96	16 66
82 75	17 25	18 73	18 42	18 12	17 82	17 52	17 22	16 91	16 61	16 31
83 00	17 00	18 37	18 07	17 77	17 46	17 16	16 86	16 56	16 26	15 96
83 25	16 75	18 01	17 71	17 41	17 11	16 81	16 51	16 21	15 91	15 61
83 50	16 50	17 66	17 36	17 06	16 76	16 46	16 16	15 86	15 56	15 26
83 75	16 25	17 31	17 01	16 71	16 41	16 11	15 82	15 52	15 22	14 92
84 00	16 00	16 96	16 66	16 36	16 07	15 77	15 47	15 17	14 88	14 58

With a view to ensuring that preventable losses are not occurring, a complete check-up of all factory operations should be carried out at frequent intervals. For this purpose *The Materials Balance Method* of Mortensen (1945) gives very accurate results.

When cream is bought on the commercial butter system. In some countries, notably New South Wales and Queensland, suppliers are paid not on butterfat but on the amount of commercial butter manufactured from the cream they supply. In such cases, the significance of overrun is somewhat different. When the cream is received it is weighed and tested in the usual way, but instead of the supplier being credited with the weight of butterfat in the cream, the quantity of butter which can be made is estimated from a chart prepared for the purpose, and the supplier is credited with the amount of butter so estimated (Brimlecombe and Treacy 1948). At the end of each month an overrun is calculated on the difference between the total estimated butter and the quantity of butter actually manufactured. This overrun is expressed as a percentage of the estimated butter, and is credited to each supplier in proportion to the total of butter calculated from the chart and already credited to him. For example, if the total estimated butter credited to suppliers from the chart were 100,000 lb. and the factory made 102,500 lb. butter, it would be said to have an overrun of 2500 lb. or 2½ per cent. A supplier who had already been credited with 400 lb. commercial butter when his cream was received, would be credited with a further 2½ per cent. making a total of 410 lb. for which he would receive payment.

Butter Grading and Butter Standards. Most countries have introduced official schemes for the examination of butter, the aim of which is to maintain a standard of quality. The official grading systems of some countries have enabled overseas buyers of exportable surpluses to purchase according to grade without the necessity of checking the quality.

Grading is also educational. The grading advice note points out any defect in the butter which enables the factory manager to take the necessary steps to overcome the cause.

National grades. Examples of National brands adopted by various countries to indicate butter of a quality officially recognised are: National Mark of England, " Lur " brand of Denmark, " Kangaroo " brand of Australia and " Fernleaf " brand of New Zealand. Some countries recognise only one official brand (for example, the " Lur " brand of Denmark). Other countries provide for several grades but permit the National Mark to be affixed only to butter of the highest grade (for example, " Fernleaf " of New Zealand and " Kangaroo " of Australia).

The characteristics taken into account in the official grading of butter are flavour and aroma, body, texture and condition (including salting).

A summary of the official grades in various countries and the scale of points used for the various characteristics of butter is set out below.

SUMMARY OF OFFICIAL BUTTER GRADING SCHEMES

Country	*Grades*	*Scale of Points*	
	Points		
England	First over 90	Flavour	50
	Second 80-89	Body and texture	20
	Third 70-79	Colour, appearance, finish	20
		Absence of free moisture	10
New Zealand	Finest (93 and over)	Flavour	50
		Body and texture	25
	First (90 to 92)	Colour (including salting)	20
		Finish	5
	Second (80-89)		
Australia	Choicest (93-100)	Flavour	50
	First (90 92)	Body and texture	30
	Second (86-89)	Condition	20
	Pastry (83-85)	--	
U.S.A.	AA (93 and over)	Flavour	45
	A (91 92)	Body	25
	B (90)	Colour	15
	C (89)	Salt	10
	Cooking (below 89)	Style	8
Eire		Flavour	60
		Body and texture	30
		Colour	5
		Packing	5
Canada	First (92 and over)	Flavour	45
	Second (87-91)	Texture	15
	Third (below 87)	Incorporation of moisture	10
	Below third	Colour	10
		Salting	10
		Packing	10
South Africa	First (90 and over)	Flavour	50
	Second (80-89)	Body and texture	40
	Third (70-79)	Colour	10
	Cooking (below 70)		

How butter is graded. The flavour of butter straight from the churn cannot be reliably determined. Therefore, official grading is usually done when the butter is several days old. Grading is preferably done in good natural light; the most satisfactory alternative is fluorescent lighting. Grading may be carried out within the temperature range 55° to 70° F., 55° F. being the optimum for this purpose. Below 55° F. neither the smell nor flavour can be properly assessed; above 70° F. butter becomes soft, the appearance oily and the flavour greasy, all of which impair judgment.

The butter trier is inserted into the butter, turned once and withdrawn. The plug is smelled immediately after its withdrawal (Fig. Bu 9). (The plug is smelled from end to end in case of sectional defect.) The body, texture and colour are observed by closely examining the surface of the core on the trier and the appearance of the fractured end of a small piece of butter broken from the plug by means of a metal spatula. The flavour is determined by completely liquefying a small piece of the butter in the mouth.

Compositional standards. There is some variation in the standard of composition prescribed for butter in different countries. In England the only standard laid down is a maximum moisture percentage of 16. The regulations in Australia and New Zealand prescribe a maximum moisture percentage of 16 and minimum butterfat percentage of 80; the legal minimum butterfat content most favoured is 80 per cent.

Butter Defects. In dealing with the defects of butter it is generally necessary only to indicate the causes when the remedial measures will be readily evident to the experienced buttermaker. Where prevention is not clearly self-evident from the cause, reference is given to the appropriate paper which may be consulted. The standard textbooks on butter may also be referred to.

1. *Flavour and aroma defects.*

Defect	*Probable cause(s).*
Flat	The absence of natural or induced cream ripening; neutralising cream to too low acidity; excessive washing of the butter granules or churning cream from cows in poor condition.
Bitter	Cream of cows in late lactation; certain yeasts in cream; brine leakage into cream; occasionally due to weeds eaten by cows.
Sour	Improper neutralisation; bacterial development.
Stale	Stale cream due to infrequent delivery; butter kept for long periods at insufficiently low temperature.
" Unclean " or " Off "	Cream of inferior quality; defective factory sanitation.
Oily, metallic, tallowy	Minute traces of copper and iron from cans and factory equipment dissolved by cream; exposure of milk or cream to sunlight.
Rancid	Fat-splitting micro-organisms in cream kept overlong under poor storage conditions.
Cheesy	Cream unhygienically produced.
Musty, mouldy	Butter parchment and/or boxes becoming wet in transport or storage; sometimes caused by musty or mouldy cream.
Fishy	High acidity, especially in stored butter.
Feedy, weedy	Milk-tainting fodders or weeds eaten by cows.
Cooked	Overheating of cream during pasteurisation. (A slightly cooked flavour usually disappears from butter kept in cold storage.)
Soda, alkaline soapy	Over-neutralisation of cream; improper mixing of neutraliser in cream leading to saponification of fats.

1. *Flavour and aroma defects.*—(*contd.*)

Defect	*Probable cause(s).*
Harsh, briny	Excessive salting; incomplete incorporation of salt.
Rabbitto, surface taint, "sectional contamination"	Bacteria of water origin (Derby and Hammer 1931, Pont 1941, Jensen 1941, Hood and White 1928).
Hammy	Flavour absorbed by cream from steam produced from impure water during direct steam pasteurisation.
Cowy	Contamination of milk due to unclean production practices.
Yeasty	Fermentation of cream by certain yeasts.

2. *Body and texture defects.*

Weak	Insufficient cooling of cream; churning at too high a temperature.
Greasy	Overworking of weak-bodied butter. Washwater of too high a temperature.
Sticky	Overworking.
Leaky	Churning fresh cream without proper chilling; overchurning; washwater of too high temperature; underworking; failing to adjust temperatures for correct churning.
Mealy, crumbly, salty, fatty	Improper control of manufacture to correspond with seasonal changes in the butterfat.
Gritty	Undissolved salt grains in butter due to soft butter incapable of being properly worked; coarse salt; salting too late.

3. *Colour defects.*

Mottled	Faulty cooling, churning and washing temperatures giving soft butter incapable of thorough working; overchurning to too large a grain; uneven distribution of salt; overloading of churn; mechanical defects in churn rollers—all factors preventing thorough working of butter, complete solution of salt, and fine dispersal of moisture droplets (Hunziker and Hosman 1920).
Streaky, wavy	Uneven working; churn rollers set unevenly; churn barrel not level; melting of surface of butter before mechanical packing; remnants of one churning mixed with another churning.
Dull	Drought; cows depastured on dry food of low nutritive value.
Toppiness, primrose colour	Drying out of surface layer in cold-stored butter (Barnicoat 1938). *See* also Stability.

Butter Factory Hygiene. Efficiently pasteurised milk or cream may soon be recontaminated, and the quality of the butter impaired through neglect in the care and cleansing of factory equipment. Some of the common sources of contamination in the factory are wooden equipment (especially churns), insanitary piping and taps, coolers, rubber gaskets and packing glands in pumps, vats and churns.

Essentials for maintaining a high standard of factory hygiene are:

1. Equipment in good mechanical and physical condition.
2. Suitable lighting and ventilation.
3. The availability of adequate supplies of hot water, steam and suitable detergents.

4. Measures for control of flies.
5. An appreciation by factory personnel of the effects of bacterial contamination.

The efficient cleansing of all dairy equipment involves the following fundamentals:

1. Thorough washing.
2. Thorough rinsing.
3. Sterilising by means of steam or chemicals.

Can washing must be efficiently carried out. The return to the farmer of improperly cleaned cans is psychologically bad. He can hardly be expected to heed the advice to maintain strict cleanliness if the factory sets a poor example. The papers by Briscoe (1947) and Scarlett (1947) may be consulted for fuller information. (*See* Churns, cleaning and sterilising.)

Vats, whether used for tipping, steaming, receiving or holding milk or cream should first be hosed with warm water to remove any remnants of milk and cream, then scrubbed with a warm detergent solution. While doing this the coils should be set in motion in vats so fitted. After running this solution out, open vats are hosed with boiling water for 10 to 15 min., and closed vats steamed with the lid closed. Any condensed water is allowed to run out and the vat kept closed until again used. It is good practice to spray vats with a 100 p.p.m. chlorine solution just prior to use. Packing glands in vats should receive periodical attention. All vats should also be kept clean externally and regularly painted.

The *vacreator* is first flushed through with water to wash away all remnants of cream. It is then filled with water to which is added 2 lb. detergent per 100 gal., the temperature raised to near boiling point and circulated through the machine. The solution is allowed to remain overnight in the machine which is dismantled next morning, and all softened casein is cleaned off before reassembling. Just before further use the machine is sterilised with steam.

Flash pasteurisers are cleaned by washing away all cream remnants with warm water, then circulating a detergent solution through the machine. The solution may be allowed to remain in the dome type pasteurisers overnight. The machine is thoroughly scrubbed and then hosed with boiling water. After reassembling for use, boiling water is circulated through the unit and through or over the cooler for about 30 min.

The *volatiliser* is cleaned in a similar manner to the flash pasteuriser, except that the vacuum chamber is thoroughly scrubbed with detergent solution.

Cream coolers are of two types—coil coolers and plate coolers. Because of the circular nature of the surface, proximity of coils to each other and the internal cooling agent (unless there is a means for emptying the water or brine before sterilisation), coil coolers are difficult to clean and sterilise. After use all remnants of cream are first hosed off. A warm detergent solution is then circulated over the coils while the coils and trays are scrubbed and sterilised, and the coils hosed for 10 min. with hot water not less than 180° F. The bottom tray is also scrubbed and hosed in a similar manner to the coils.

Plate coolers are cleaned in conjunction with the pasteuriser by first passing through water to remove traces of cream, followed by the detergent solution for 5 to 10 min. The plates are then loosened, and all surfaces which were in contact with cream, scrubbed and finally hosed with scalding water. After reassembling the next day, hot water is pumped through for 10 min. to near-sterilise the unit.

Wooden butter churns. The following methods are outlined for the cleaning of butter churns, consideration being given to economic use of cleaning compounds.

Before churning. Run into the churn (40 box capacity) approximately 50-100 gal. of water at a temperature of 180° to 200° F. and revolve the churn in high gear for 3 to 5 min. Drain rapidly. Run in 50 to 100 gal. of chilled water to prevent butter sticking to the churn. Revolve for 5 min. and drain. Many factories omit the hot water before use and instead use 200 p.p.m. chlorine in the cold water rinse.

After churning. First rinse. Run quickly into the churn 50 to 100 gal. of water at a temperature of 180° to 200° F. and revolve the churn in high gear for 3 to 5 min. Empty quickly and wash out any fat at the bottom of the churn with hot water, before closing the cocks for the second rinse. This first rinse gets rid of excess fat and the whole process should be done speedily, with high temperature water.

Second rinse. This is done with an alkaline detergent solution. Fill the churn one-quarter to one-third full with water at a temperature of at least 200° F. and add 1 lb. of soda ash to each 100 gal. of water in the churn. If the water is hard, add slightly more soda ash. Place the door on, with the sight glass removed, and revolve for 2 min. in high gear with the rollers working, and then in high gear for another 10 min. Stop the churn and drain quickly.

Final rinse. Refill the churn one-quarter to one-third full with hot water, at a temperature of 200° F., sight glass removed from door, and swing for 15 to 20 min. in high gear with the rollers in action for the first 3 to 5 min. Stop the churn, drain, and allow it to dry out by standing with the cocks open at the highest point of the churn. After the final rinse, the temperature of the water as it comes from the churn should be taken; if it is over 180° F. the treatment can be considered satisfactory. Experiment will soon show how much water, at a particular temperature, is required in the churn to give 180° F. after swinging.

An alternative final rinse recommended by McDowell (1941) is to add 6 gal. of clear lime-water to each 100 gal. of hot water in the churn, raising the temperature of the water in the churn to 200° F. by means of a flexible metal steam hose, fitted with a silencer. This method is claimed to keep the surface of the churn smooth and hard and prevents the butter from sticking to it.

Butter trolleys, butter packing and cutting machines, cream pumps, cream pipelines and taps should be carefully cleaned and hosed with boiling water.

Factory floors, drains and sumps should be hosed down daily to remove all remnants of milk and cream, swept with a detergent solution, using a stiff broom for the purpose, and finally hosed with hot water.

Factory employees should be of clean habits and neatly dressed in clean, white overalls.

(*See also* Butter, renovated; Chlorine; Cleaning and sterilising; Detergents; Margarine; Packaging; Utilisation.)

Microbiology of butter. ***Butter as medium.*** Butter is a less favourable medium for micro-organisms than most other dairy products. It is an emulsion in which water is the dispersed phase and fat the continuous system. In contrast, water is the continuous phase in cream, churning involving an inversion of the phases. The bacteria are mainly left enclosed in the resulting droplets of moisture which, in well-worked butter, are so finely dispersed as to restrict bacterial proliferation, except in the larger droplets. The migration of bacteria from one droplet to another is apparently rare. Butterfat itself is relatively resistant to bacterial action. Although the nutrients are adequate, the brine concentration in the serum of salted butter retards the growth of most bacteria, the effect being considerably reduced in butters of low salt content. On the other hand, the *p*H of the serum of butter made from sweet or neutralised pasteurised cream, commonly falls within the range of *p*H 6·0 to 8·0 which is conducive to the growth of the common contaminants of butter. In starter-ripened butter, however, the lower *p*H retards bacterial growth, but not yeasts and moulds.

Counts of butter. Raw milk and cream have a very mixed microbial flora, which may be of the order of many millions per ml. in sour cream. Pasteurisation at the high temperatures of 180° to 205° F. permissible in the butter industry, effectively destroys all but certain thermoduric cocci, which, being generally inert, cause little damage to butter quality. The plate count of the cream immediately after pasteurisation normally varies from less than 1000 to 100,000 bacteria per ml., depending on the initial quality of the cream and the system of pasteurisation. Counts exceeding 100,000 per ml. sometimes occur after the pasteurisation of farm-separated cream when deliveries to the factory are infrequent—*e.g.* twice weekly. The higher temperatures used in vacreation generally result in lower counts than other methods of pasteurisation.

Recontamination, depending in extent on factory hygiene, occurs from factory equipment (especially wooden churns), water, air, and personnel. A large proportion of the bacteria in the cream are removed with the buttermilk. Those remaining enmeshed in the butter granules, together with those added during the working and packing processes, represent the total bacterial count of the finished butter. Where good factory sanitation prevails, butter made from pasteurised cream should have a plate count on milk agar of not more than 100,000 bacteria per g. and total yeast and mould count of less than 100 per g. at the time of grading—usually when 4 days old (Queensland Butter Improvement Service tentative standards).

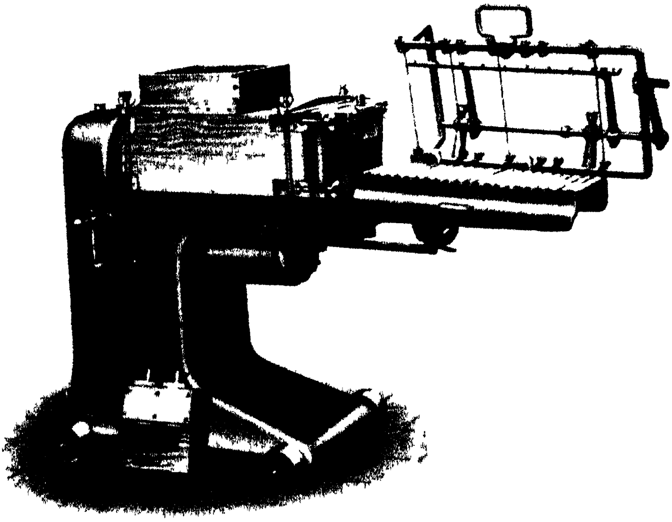
In the U.S.A. the yeast and mould count is the standard test for checking factory sanitation. In Australia total plate counts and coliform tests are considered necessary in addition to the yeast and mould count, the latter being regarded as indicative of churn contamination.

Growth. Rapid bacterial multiplication can occur in butter, especially if unsalted, if storage temperatures are inadequately controlled. Apart from the type of initial contamination, the developing flora will depend on the temperature. Commercial cold storage at temperatures below freezing point usually prevents the proliferation of bacteria and, although not by any means completely destructive, does often cause some decrease in numbers (Rice 1938). At temperatures of 40° to 50° F., cryophilic bacteria, including many typical water-inhabiting species, slowly develop. Lactic acid streptococci, which usually occur as contaminants from factory equipment, and micrococci, grow relatively well in butter stored between 60° and 70° F. Maximum bacterial multiplication is reached in the vicinity of blood heat, 98·6° F., the coliform bacteria in particular growing rapidly. Off flavours quickly develop in butter kept above 65° F. The influence of temperature on the rate of growth of bacteria in butter is appreciably modified by the physical condition (degree of dispersal of the water droplets) and the salt concentration in the butter serum. Bacterial growth in butter has been exhaustively reviewed by Hammer and Long (1941).

Bacteriological examinations of butter are regularly carried out in control laboratories in all butter-producing countries, with the primary object of controlling factory sanitation and not as a measure of grading characteristics. There is no positive correlation between bacterial numbers and the initial flavour of butter made from sour cream which has been neutralised and pasteurised. However, Gilmour (1933) states that for unneutralised sweet cream butter the *p*H, which chiefly measures the activity of the pre-pasteurisation flora, is closely correlated with flavour score; low *p*H implies the inclusion of inferior cream.

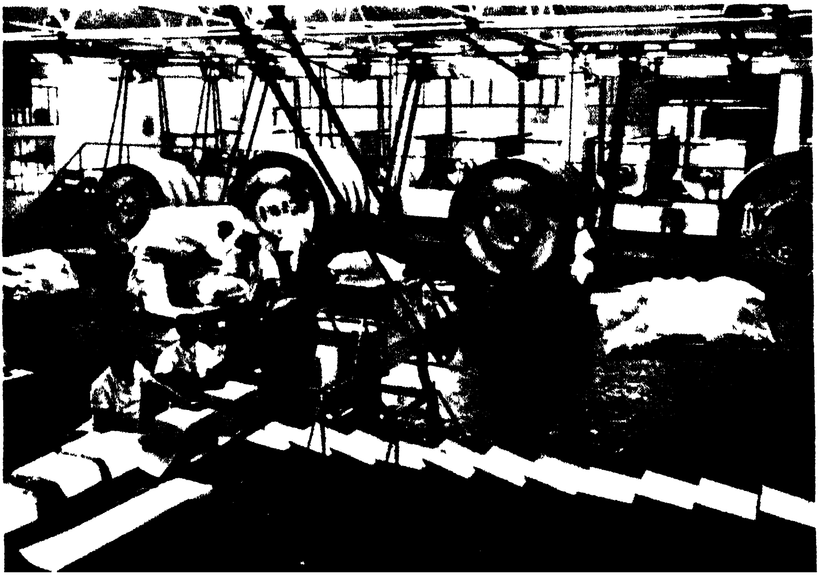
The keeping quality of butter under storage, transport and handling conditions (particularly in shops and homes) does, however, bear some relationship to the degree of bacterial growth possible under the limitations mentioned previously. In this respect the bacterial species present are equally as significant as the actual numbers.

Refs.: King (1953), *DSA*, **15**, 589 (theory of churning); Barnicoat (1948), *N.Z. J. Sci. and Tech.*, **29**, 199; (1945), **27**, 343; (1938), **19**, 546; Loftus Hills (1948), *Aust. Dairy Rev.*, **16**, (8), 7; Ruehe (1947), *CDIC*, **26**, (8), 48; Brimblecombe and Treacy (1948), *Qld. Ag. J.*, **66**, 287; Hammer (1947), *Aust. J. Dairy Tech.*, **2**, 62; Briscoe (1947), *DI*, **12**, 127; Scarlett (1947), *DI*, **12**, 430; Pont (1946), *J.C.S.I.R. Aust.*,



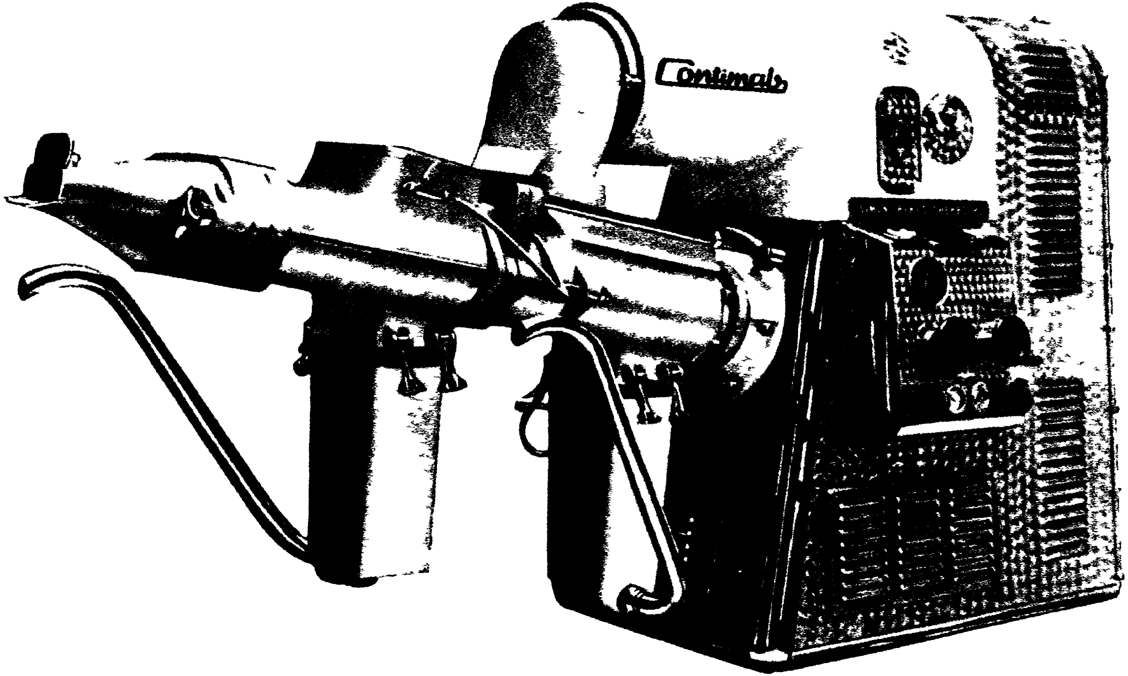
[By courtesy of Huon & Rempler Ltd

FIG. Bu 8.—*Butter Extruding and Cutting Equipment*



[By courtesy of United Dairies Ltd

FIG. Bu 9.—*Weighing and Packing Butter*



[By courtesy of Simon Freres, Cherbourg

FIG BuM1 —*Continuous Butter-making Machine*

19, 432; Loftus Hills (1946), *Aust. J. Dairy Tech.*, **1,** 43; Taylor, Coop and Buchanan Smith (1946), *B.I.O.S. Final Report*, No. 85; McDowall (1946), *N.Z. Dairy Exp.*, **21,** (12), 28; **22** (1), 34; **22** (2), 34; Mortensen (1945), *Res. Bul.* 337, *Iowa Ag. Exp. Station;* Pont (1941), *J.C.S.I.R. Aust.*, **14,** 1; Jensen (1941), *Vic. Ag. J.*, **39,** 283; Hammer and Long (1941), *Bact. Rev.*, **5,** 337; McDowall (1941), *N.Z. J. Sci. and Tech.*, **23,** 146*A*; Kretschmar (1940), *W.A. Ag. J.*, **17,** 93 and 141; Riddet, Smith, Beatson and Whitehead (1940), *N.Z. J. Sci. and Tech.*, **21,** 292*A*; Wiley (1939), *N.Z. D.R.I. Pub.*, 125; McDowell (1938), *N.Z. J. Sci. and Tech.*, **19,** 682; Rice (1938), *Qld. Ag. J.*, **50,** 708; Barnicoat (1938), *N.Z. J. Sci. and Tech.*, **19,** 556; McDowell (1937), *N.Z. J. Sci. and Tech.*, **18,** 725, 733, 818; (1938), **19,** 38, 296, 345; (1947), **28,** 132; Lyons and O'Shea (1936), *Proc. Royal Soc.*, Dublin, **3,** 1; Gilmour and Arup (1935), *Eire Ag. J.*, **33,** 23; Loftus Hills, Scharp and Bellair (1934), *JDR*, **5,** 124; Gilmour (1933), *Eire Ag. J.*, **32,** 273; Valentine (1932), *N.Z. D.S.I.R. Bul.*, 36; Udy (1931), *N.Z. D.S.I.R. Bul.*, 33; Derby and Hammer (1931), *Res. Bul.*, 145, Iowa Ag. Exp. Sta.; Combs, W. B. (1928), *World's Butter Review;* Hood and White (1928), *Can. Dept. Ag.*, Pamphlet 91; Rahn (1922), *Kolloid Z.*, **30,** 341; Hunziker and Hosman (1920), *JDS*, **3,** 77; Fischer and Hooker (1917), *Fats and Fatty Degeneration* (New York), p. 193; Munro and Barnicoat (1953), *JDR*, **20,** 274 (fisheries). *See* also McDowall; Wilster; Totman, McKay and Larsen; Hunziker (B).

BUTTER—LABORATORY EXAMINATION. Usually butter is examined bacteriologically for the numbers of potential fault-producing organisms, especially yeasts, moulds, and the lipolytic, gelatine-liquefying types of gram-negative organisms. As these usually grow readily on ordinary media, special media are not necessary, but care should be taken to incubate plates at low temperatures, *e.g.* about 40° F. as well as at 70° F., as certain organisms may produce characteristic faults only at low temperatures. *See* Media; Stability.

Refs.: B.S. 769 (1952) (chemical); Hiscox and House (1951), *JDR*, **18,** 291 (effect of reworking and blending); Mohr and Baur (1950), *M*, **5,** 215 (det. solidifying point); Thomson (1950), *JDR*, **17,** 66 (*Pseudomonas*); Bang (1949), *IDC*, **3,** 391 (synthetic flavour); Veerdig 480 (storage); Hietaranta (1949), *IDC*, **2,** 472; Holm and Woode (1949), *IDC*, **2,** 325; Mattsson (1949), *IDC*, **2,** 308; Mulder (1949), *IDC*, **2,** 81; Reinart (1949), *IDC*, **2,** 392 (oxidation); King and Fritz (1948), *M*, **3,** 3, 36, 75, 97 (structure); Mohr and Baur (1948), *M*, **3,** 17 ("oiling off"); Mohr and Wellm (1948), *M*, **3,** 234 (consistency); Schmalfuss (1948), *M*, **3,** 225 (taints in fat); Mohr and Hennings (1947), *M*, **2,** 173 (dielectric constant); Sell (1947), *M*, **2,** 310, 321 (theory of churning); B.S. 895 (1940) (microbiological); Pont (1941), *JDR*, **12,** 24 (error of plate count); Moir and Russell (1939), *JDR*, **10,** 310 (simplified methods); Hiscox (1936), *JDR*, **7,** 238.

BUTTERFAT. The fat in milk, butter, or any pure milk product.

BUTTER, JOGHURT BUTTER PROCESS.

Ref.: Todoroff (1947), *M*, **2,** 437.

BUTTERMAKING MACHINES. Much interest is being evinced in new methods of making butter developed in several countries in recent years. In principle the new processes may be sub-divided into (*a*) Separation Processes, and (*b*) Accelerated Churning.

Separation processes. These are "New Way" (Australian), "Alfa" (Swedish), Cherry Burrell and Creamery Package Co. (U.S.A.) machines. They depend on separating the milk to give ordinary cream, reseparating this to a butterfat content of 80 per cent. or more, and then chilling. Inversion of the emulsion occurs at various stages—with the Cherry Burrell process before and during separation, with the Creamery Package Co. after separation, and with the Alfa and New Way processes during chilling.

Churning processes. The Fritz and Senn machines, developed in Germany and Switzerland respectively, depend on a modified and accelerated form of churning by means of high-speed agitators.

A brief description of the new machines, the fundamental principles of their operation and the possible repercussions on the butter industry have been discussed by McDowall (1946).

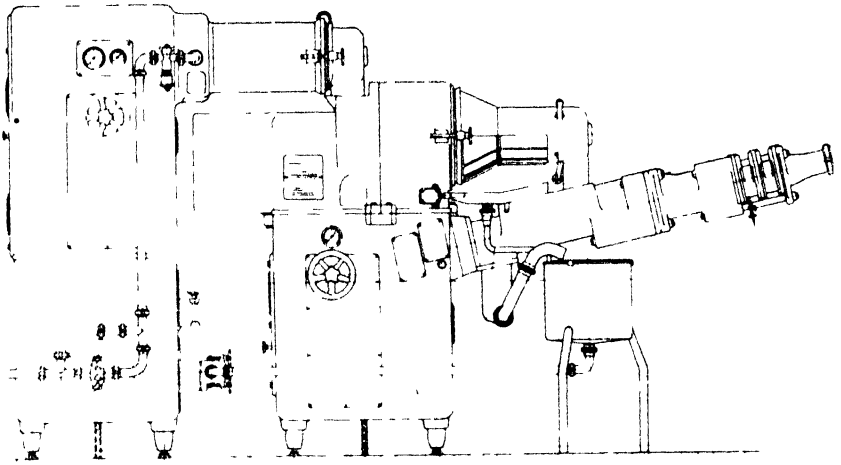
Separating Methods. 1. ***Alfa process.*** The milk is preheated to 113° to 122° F. and passed to a hermetic Alva-Laval separator to yield cream of 25 to 35 per cent. fat content: this separator has a capacity of up to 1100 gal. per hr. The cream is then pasteurised in a vacreator, plate or dome-type pasteuriser, at a temperature of up to 203° F., cooled to 130° to 135° F. and reseparated in a special separator to the fat content desired in the butter. The " plastic " cream is then pumped through the transmutator, where the change from cream into butter takes place. The transmutator consists of three jacketed stainless steel cylinders, each about 1 ft. diameter and 6 ft. long. Inside each cylinder rotates a stainless steel drum fitted with raised spiral strips. The brine enters the bottom cylinder at a temperature of 25° to 40° F. and flows in the same direction as the cream; the cream leaves this first cylinder at about 68° F. In the next cylinder the inversion of phase from fat-in-water to water-in-fat type of emulsion is completed. The butter comes from this cylinder at 48° to 52° F., and is very viscous. Little refrigeration is applied to the third cylinder which is in effect a temperature-controlled working section. The butter leaves the third cylinder at 52° to 57° F. in a semi-fluid form, and is packed directly into the boxes. Solidification takes place at once and is completed in the cool room, the product being similar in appearance to butter produced by churning. Normal output is about 6 cwt. per hr.

The Alfa process appears to have given satisfactory results in European countries, although the product has not been free of texture troubles. Preliminary trials in Australia and New Zealand (Loftus Hills 1948, McDowall and McWhirter 1948) indicate some modifications in plant and treatment may be necessary for the special conditions in those countries.

2. ***Cherry Burrell process.*** This process (Ruehe 1947), has been developed for the treatment of acid cream, but will also treat sweet cream. The cream is pumped from the receiving vats, through an agitating heater to destabilise the emulsion, and then directly to the centrifugal separator which concentrates the cream up to 86 to 90 per cent. fat content and breaks the emulsion. An automatic desludging type of separator is used. The butterfat containing dispersed serum is next pasteurised in a vacreator, cooled to 110° to 115° F. and passed into standardising vats. The standardising for acidity, moisture, and salt content is an intermittent process. After standardisation, the cream is pumped through a chiller resembling an ice-cream freezer, and cooled to 40° F.: it then passes through a texturator which allows crystallisation of the fat to become more complete and provides a later slight working by flow through a perforated plate. The butter emerges through a mouth-piece into the packing machine or bulk container. The whole process takes about 1½ hr. Output is about 2000 lb. per hr.

3. ***Creamery Package process.*** This is described as a strictly continuous process (Ruehe 1947), taking only about 10 min. from the time the cream is pumped from the receiving vat to the final packing of the butter. The cream is tipped into a receiving vat, from which it is pumped to a pasteuriser and heated to 170° F. A vacreator may be used instead, if the quality of the cream requires it. The cream then goes through the separator to concentrate the butterfat percentage to 75 to 80, and is then passed through an emulsion-breaker which inverts the emulsion from a fat-in-water to a water-in-fat system. In the next stage, the butterfat in the cream is concentrated to 98 per cent. in a gravity separating chamber. The serum from this chamber is passed back to join the cream which is on its way to the separator for concentration and thus the fat in the serum is recovered. The 98 per cent. butterfat mixture is pumped through a standardising pump where the necessary amount of water or serum and salt is added to ensure butter of the desired composition. The standardised mixture is next passed through a " chiller crystalliser " in order to harden it and to ensure the even dispersal of the moisture and salt in the butter and the desired physical characteristics. An extruder enables the butter to be passed directly into a butter cutting machine for packing in retail-size prints or bulk packing in boxes. Output is about 2000 lb. per hr.

4. ***New Way process.*** In this process (Loftus Hills 1946, Lynch 1946) the wholemilk is separated to give cream of about 40 per cent. fat content, or sweet cream may be received direct from the farmers. The 40 per cent. cream is flash-pasteurised, cooled to 140° F., and at this temperature put through an airtight centrifugal separator to concentrate the butterfat content to 80 per cent. (As with the Alfa process, there is some prospect of treating neutralised acid cream by using a self-sludging separator.) The thick cream is next drawn through a float-valve chamber into vacuum storage and standardising vats which are fitted with agitators and are water-jacketed. The salt is added to the cream in the float-valve chamber and becomes completely dissolved by the agitation in the standardising vat. Very accurate standardisation of the composition of the butter is practicable in the standardising vat. To change the emulsion and to give the desired physical character, thus converting the plastic cream into butter, is the next stage; this is effected in the extruder. It consists of two spiral geared hollow cylinders which revolve in counter direction in a close-fitting brine-jacket and which are also brine-cooled internally. The cylinders have square-cut threads which intermesh. The cream, in being forced forwards through the extruder, is rapidly chilled and solidified and then goes through either a box moulder for packing into 56 lb. boxes or a pat moulder for wrapping 1 lb. and ½ lb. prints. The outlet temperature is about 35° F. Output is at the rate of 1400 lb. per hr.



[By courtesy of AG Westfalia.

FIG. BuM 2.—*Section of a continuous buttermaking machine.*

Another type of machine is illustrated in Figs. BuM 1, 2 and 3.

5. ***Fritz process.*** Work on this process began in Germany in 1939, and over 40 plants were in actual use in commercial factories in 1946 (Taylor, Coop, and Buchanan Smith 1946). The milk is pumped from the receiving vats to a separator from which cream of 45 to 50 per cent. butterfat is obtained. The cream is pasteurised at 203° F., cooled to 43° to 50° F. and held for some hours, or overnight, and in a storage vat or tank. It is next pumped to a small control

container which maintains the flow of the cream at a constant pressure and adjustable rate. The special process commences beyond this stage. The cream passes into a small water-jacketed cylinder, approximately 10 in. long and 10 in. diameter, kept cool by circulating cold water through the jacket. High speed vanes in this cylinder churn the cream into butter in about 1½ sec. The buttermilk and butter granules drop into an inclined section fitted with two worms about 18 in. long and 6 in. in diameter which rotate in opposite directions. Here the buttermilk runs off, and the butter is forced through a perforated plate from the further side of which it is removed by rotating blades. It emerges as a ribbon 3 × 1½ in. in cross-section. It can be packed direct into boxes or cut into retail-size pats by means of a Benhill cutting and wrapping machine. Output of the larger model of the machine is about 2000 lb. per hr.

Reports on Canadian and U.S.A. trials with the Fritz machine (Pearce 1947, Ruehe 1947) suggest some difficulty is experienced in securing butter of uniform composition and all samples exceeded 16 per cent. moisture, the legal maximum permitted in most British countries. Recent work in Germany, however, using different screw speeds, indicates that the moisture content may be kept below 16 per cent. and may be accurately controlled.

6. ***Senn process.*** This process was developed in Switzerland. The cream is pasteurised, cooled and held as for normal churning. Batches of 50 gal. are admitted to a metal churning chamber and submitted to a pressure of carbon dioxide. Violent agitation in this chamber converts the cream into butter in 1½ to 2 min. A volume of cold water, equivalent to the volume of buttermilk, is used to wash the butter granules. The butter granules are then dumped on to screws which separate the wash water, work the butter and convey it to the moulding and packing machine. The whole process takes only 5 to 8 min., and one man only is needed for the churning operation. The hourly out-turn of butter is about 1800 lb. per hr. for the largest model of the machine.

Refs.: Wiechers and de Goode (1950), *Continuous butter making*, Amsterdam; King (1953), *DI*, **18**, 783, 1098; King (1952), *DSA*, **14**, 225; Hovos (1951), *M*, **6**, 201 (water in "Fritz" butter), Dobinsky (1950), *M*, **5**, 110 (water content); Kellermann (1950), *M*, **5**, 187, 216 (keeping quality); Mandt and Orr (1950), *NBCJ* (1), 24; Mrozek and Keller (1950), *M*, **5**, 179; Mohr (1949), *IDC*, **3**, 150; Wigan, 165; Weinreich, 172; King, 180; Mohn and Baur (1949), *M*, **4**, 100 (form of fat); Stigen *et al.* (1949), *IDC*, **3**, 139; Schulz and Schulz (1948), *M*, **3**, 213, 253; Schulz (1947), *M*, **2**, 293; Wilsmann (1947), *M*, **2**, 303; McDowall (1946), *N.Z. Dairy Exp.*, 21, **12**, 28; 22, **1**, 34; 22, **2**, 34; Loftus Hills (1948), *Aust. Dairy Rev.*, 16, **8**, 7; McDowell and McWhirter (1948), *N.Z. J. Ag.*, 77, **1**; Ruehe (1947), *Can. Dairy J.*, 26, **8**, 48; Taylor, Coop and Buchanan Smith (1946), *BIOS*, Reports Nos. 85 and 770; Pearce (1947), *Can. Dairy J.*, 26, **3**, 41; Loftus Hills (1946), *Aust. J. Dairy Tech.*, **1**, 43; Lynch (1946,) *N.Z. Dairy Exp.*, 21, **7**, 18.

General refs. on butter: Hunziker (*B*); Richmond; Rogers; Walker-Tisdale, Dearden and Robinson (1943), *Practical Buttermaking*, London; Totman, McKay and Larsen (1939), *Butter*, London. McDowall (1953) *The Buttermaker's Manual*, Wellington, N.Z.

BUTTERMILK. Buttermilk is a liquid byproduct of the manufacture of butter from cream and will be sweet or sour according to the nature of the cream used. Typical analyses are given in Tables BuM 1 and 2.

In America there is a considerable demand for cultured buttermilk which is a culture of *Str. lactis* and *Str. cremoris* in buttermilk, but this type of cultured buttermilk is not sold in this country. Buttermilk is commonly mixed in with whole or skim milk for powder making or may be used for feeding stock. Mulder *et al.* ((1953) *IDC*, **2**, 486) suggest that the characteristic flavour is associated with the oxidation of lecithin, etc., and the destruction of ascorbic acid. For the preparation of cultured buttermilk *see* Burke, and Whittier and Webb.

TABLE BuM 1.

	Sweet cream *per cent.*	*Ripened cream* *per cent.*
Water	91	91·6
Fat	0·35	0·5
Lactose	4·4	3·4
Lactic acid . .	0·01	0·5
Protein	3·5	3·3
Ash	0·73	0·65
Specific gravity . .	1·0331	1·0314

Refs.: Hunziker (*B*); McDowall and McDowell (1949), *JDR*, **16**, 227 (fat losses in churning).

TABLE BuM 2

(Hunziker B)

Constituents in buttermilk	*Van Slyke* (1)	*Storch* (2)	*Snyder* (3)	*Vieth* (2)	*Fleischmann* (4)	*Storch* (2)	*Richmond* (2)
	%	%	%	%	%	%	%
Water . .	90·6	90·93	90·5	90·39	91·30	89·74	90·98
Fat . .	0·1	0·31	0·2	0·50	0·50	1·21	0·35
Casein . .	2·8	3·37	3·3	3·60	3·50	3·28	3·51
Albumin .	0·8						
Milk sugar .	4·4	4·58	5·3	4·06	4·00	4·98	4·42
Lactic acid .	0·6		-	0·75			0·01
Ash . .	0·7	0·81	0·7	0·80	0·70	0·79	0·73

Specific gravity of sweet-cream buttermilk 1·0331 (2).
Specific gravity of sour-cream buttermilk 1·0314 (2).

(1) Van Slyke, L. L., *Modern Methods of Testing Milk and its Products* (1916).
(2) Richmond, H. D., *Dairy Chemistry* (1899).
(3) Snyder, H., *Dairy chemistry* (1914).
(4) Fleischmann, W., *Lehrbuch der Milchwirtschaft* (1915).

BUTTERMILK POWDER. Buttermilk powder may be prepared by roller of spray process. In this country it is used almost entirely for animal feeding. Experiments in its use for confectionery, bakery products, etc., have shown that a very variable fat content (10 to 25 per cent.) is a considerable disadvantage in processing, and the high acidity normally present leads to rapid deterioration of the fat. In bad cases a rancid oily type of flavour may be produced.

Ref.: Whittier and Webb.

BUTTER, RENOVATED. Renovated butter, also known as Processed butter or Rechurned butter, was first developed about 70 years ago in the U.S.A. and later in many other countries. It is made by melting butter (usually material which has deteriorated during storage), clarifying and washing the separated fat, emulsifying this with fresh or ripened milk and converting the creamy emulsion into butter.

The principal methods are either that used for churning butter or that for churning margarine. In both cases the first step is to obtain from the rancid or " off quality " butter a purified clean-tasting fat. This is achieved by melting the butter in jacketed pans with hot water at a temperature of 45° to 55° C.

and separating the fat from the aqueous phase. If the butter is badly infected with micro-organisms, pasteurisation temperature may be used, but the fat may become rather susceptible to oxidation at these higher temperatures. The fat is washed with warm water and the curd removed. If, as is frequently the case, the fat contains more than 0·5 per cent. free fatty acids, neutralisation of excess acids down to about 0·1 f.f.a. is carried out by treatment with bicarbonate of soda, and occasionally with lime. Neutralisation is followed by further washing with warm water or warm salt solution; this treatment removes water-soluble impurities and rancidity products. At one time air-blowing of the molten fat was practised to aid deodorisation, but although this was done at moderate temperature the risk of oxidation and damage to the fat was considerable and the method has been abandoned.

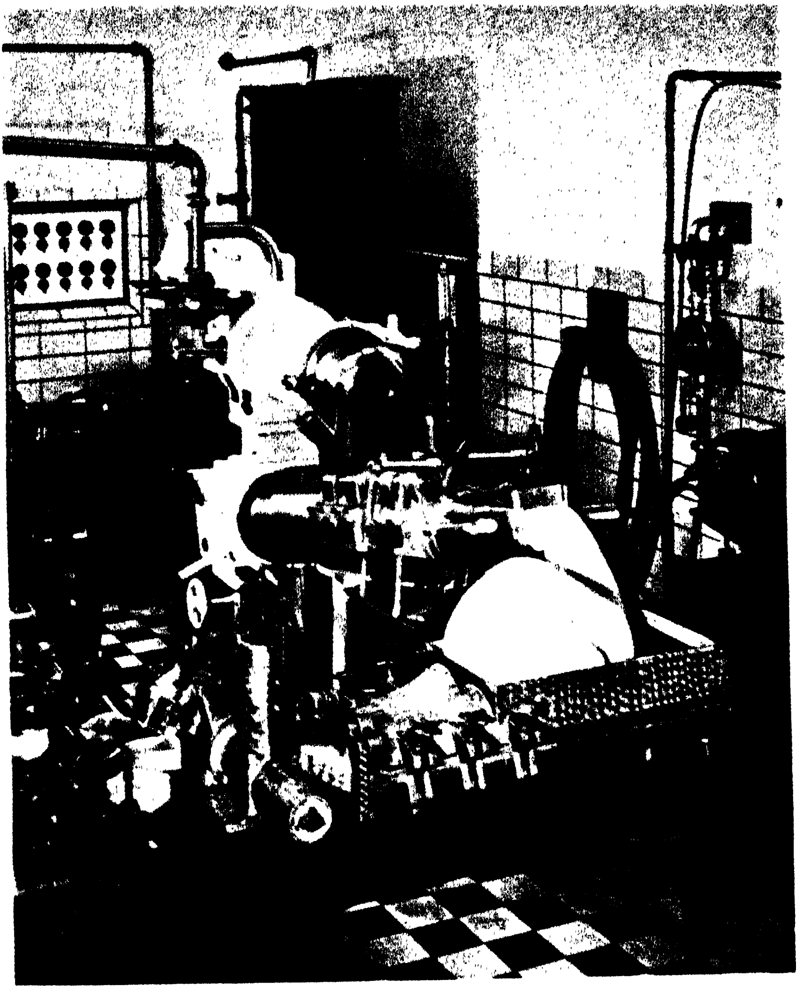
In the " butter churning " method, the liquid fat is emulsified with fresh or ripened milk or skim milk in such proportions as to form a dispersion of 15 to 50 per cent. fat in milk, and after churning at about 30° C for a short time the emulsion is cooled by spraying it with cold water (1 to 4° C.). The solidified butter grains are separated from the buttermilk and kneaded. Some manufacturers use fresh skim milk as basis for the cream and after emulsification pasteurise and ripen the cream. After ripening, churning proceeds as above.

By the " margarine churning " method—which aims at the immediate production of a dispersion of water in fat—the purified fat is mixed in churns of the jacketed tinned steel vessel type with 16 to 20 per cent. fresh or ripened skim milk, and when a thick emulsion is formed it is solidified by quenching with ice water and draining, or by crystallizing it on chilled rollers; in either method the grainy product is kneaded and plasticised on rollers and salted if required.

Although these processes were originally devised to " renovate " low-grade or rancid butter, there have been occasions when in order to save refrigerated transport and storage space and to preserve the butter fat against too rapid deterioration, fresh high-grade butter has been melted, the fat separated at temperatures of about 50° C., clarified in centrifuges and packed in hermetically closed or gas-filled tins. In this manner the fat can be kept in good condition for a long period and subsequently be rechurned into butter. It is, however, very difficult to produce rechurned butter of equal flavour quality to the original fresh butter and of the same physical and texture characteristics. The method was tried during the war.

There is no difference between butter and renovated butter in chemical comparison. The fat is butterfat as present in the original butter, and the other constituents are the same and in the same proportions as those in butter. Physical and practical tests frequently offer a distinction between the products. Butter, when examined under the polarisation microscope, shows a dark field because of its non-crystalline nature, whereas in renovated butter the melted and resolidified fat shows the presence of many crystals. The test, however, is not infallible, as renovated butter made by the " butter churning " process often appears under polarised light like genuine butter. A practical test often used is to heat the sample in a basin over a naked flame, when butter will lose its moisture while foaming gently and with the formation of an even fine powdery brown precipitate, whereas renovated butter will splutter while the water boils off and the curd will be coarsely granular. This test is not infallible, either, as a very small addition of emulsion stabiliser of the type used in the manufacture of margarine prevents spluttering and causes the curd to form a fine precipitate.

In some countries the manufacture and sale of renovated butter is subject to statutory regulations. Detection of infringement of the regulations is, however, often difficult. In this country the definition of butter as " the substance usually known as butter made exclusively from milk " provides the only, but not very definite, guidance.



[*By courtesy of AG Westfalia.*

FIG. BuM 3.– *Continuous Butter-making Machine.*

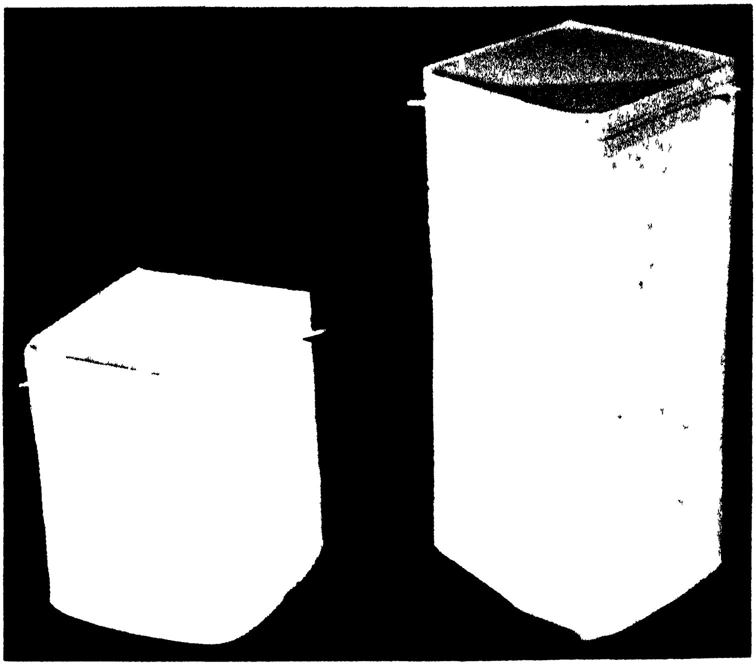


FIG. Car 1 —*Square Type of Carton (non-waxed)*

[*Photos by courtesy of British Milk Carton Co Ltd*

BUTTER, REWORKED. Reworking of butter invariably increases the count and also increases the size of the water globules. It also usually shortens the life of the butter, but there is little or no correlation between bacterial counts and keeping quality. Reworking also reduces the moisture content by 0·5 to 1 per cent.

In reworking and blending, it is customary to add water to bring the moisture content back to its original value or even to raise it to just below 16 per cent. Such water may easily result in contamination of the butter. Reworking and blending are necessary today for commercial reasons as otherwise inferior quality butter could not be sold.

In Finland up to about 1924 chemical deterioration in butter was more common than bacteriological deterioration, on account of the high acidity due to the ripening of the cream to obtain flavour. Later, the use of the A.I.V. salt (a mixture of sodium phosphate and sodium bicarbonate) to neutralise the acidity became general, and the proportion of chemical and bacteriological defects changed sharply. The chemical defects almost disappeared and the number of bacteriological defects rose sharply. In 1939 when control was taken off the number of both chemical and bacteriological defects rose markedly, the proportion of butters unsatisfactory from the bacteriological point of view being as high as 25 per cent.

Mould spores in butter appear to be able to produce ketonic rancidity without the spores actually growing.

See Stability.

Ref.: Prentice (1954), *DI*, **19**, 37;

BUTTER YELLOW. Yellow coal tar dyes, particularly chrysoidine and dimethyl amino azobenzene. A pink colour is obtained when a little hydrochloric acid is added to milk, or butter, to the skim milk or curd if this dye is present.

BUTTONS IN CONDENSED MILK. These occur as brownish lumps of curd of a cheesy appearance, and are due to enzymic action as a result of growth of the mould *Aspergillus repens*. *See* Condensed milk ; Stability.

BUTYLENE GLYCOL. This can be formed in butter cultures (starters) by the reduction of acetoin by *Str. citrovorus* and *Str. paracitrovorus*.

$$\underset{\text{acetoin}}{CH_3—CO—CHOH—CH_3} \xrightarrow{2H} \underset{\text{2 : 3 butylene glycol}}{CH_3—CHOH—CHOH—CH_3}$$

The reduction is favoured by moderate temperatures and low acidities.

Ref.: Prescott and Dunn.

BUTYRIC ACID. A simple straight chain organic acid $CH_3—CH_2—CH_2—COOH$, associated with rancidity in dairy products and with the " stormy fermentation " test for milk quality. Rancidity may be due to lipase production by certain moulds and bacteria or to the native lipase of milk itself. The characteristic stale, sweaty odour of butyric acid is not due to the pure acid but probably to some condensation-oxidation compounds.

Ref.: Bloor.

BUTYRIC ACID BACTERIA. The common name for *Clostridium butyricum*, one of the non-pathogenic saccharolytic anaerobes. *See* Classification.

BUTYRIC ACID BACTERIA, TEST FOR. *Test for Butyric Acid Bacteria* (" Stormy Fermentation Test ").—Place 10 ml. of the milk to be tested in each of three test tubes. Add to each a layer of melted paraffin wax about 1 cm. thick (this is advisable but not essential). Heat the tubes to 80° C. for 20 min. (using a thermometer in a control tube) and incubate at 37° C. for 2 days. A clot which is torn up by gas, exudation of whey, and the production of a pinkish colour, especially at the surface, indicate a positive reaction which may be confirmed by the detection of a smell of butyric acid. If two out of the three tubes give negative reactions the milk may be considered satisfactory from the point of view of freedom from butyric acid and similar bacteria. An outstanding advantage of this test is that no media, plates, pipettes, etc., are required.

BUTYRIC ACID FERMENTATION. Certain bacteria particularly *Cl. butyricum* (*see* Butyric acid bacteria) produce large amounts of butyric acid by the fermentation of sugars. The acid probably arises from the condensation of 2 molecules of aldehyde.

Glucose → triose → pyruvic acid → aldehyde
2 mols. aldehyde → aldol → butyric acid.

Acetic acid, carbon dioxide, hydrogen and a little formic acid are also produced.

Refs.: Prescott and Dunn; Stephenson; Blau (1950), *M*, **5**, 149 (antibiotic against).

BUTYRIN. The ester of glycerin and butyric acid (glyceryl tributyrate or tributyrin) present in butter fat to the extent of about 4 per cent. *See* Fat ; Media.

BUTYRINASE. A lipase or fat-splitting enzyme which can split butyrin into glycerol and butyric acid. *See* Enzymes.

BY-PRODUCTS. A general name applied to all materials other than the desired product in any manufacturing process. The following are important by-products in dairying :

Main product	*By-product*
Cream	Separated milk
Butter	Buttermilk
Cheese	Whey

In some cases the by-product is produced in the larger amount, *e.g.* if cheese is made to procure albumin or lactose, the cheese becomes the by-product. *See* Butter ; Cheese ; Cream ; Management of creameries ; Pigs ; Separated milk ; Utilisation ; Whey.

Ref.: Whittier and Webb.

C

CACCIOCAVALLO. *See* Cheese, p. 185.

CAERPHILLY, *See* Cheese, p. 185.

CALANDRIA. *See* Condensed milk.

CALCIFEROL. The chemical name for vitamin D_2. *See* Vitamins.

CALCIUM. After potassium, calcium is the richest mineral constituent in cows' milk forming about 20 per cent. of the ash (as CaO) (p. 57). It is this high proportion which makes cows' milk such a good source of calcium in the human diet and also accounts for the firm curd-forming and cheese-making properties. A further effect of this high proportion of calcium is the tendency to indigestibility of large quantities of raw milk in some persons.

Considered in terms of radicals, potassium slightly exceeds calcium, and calcium phosphate constitutes more than half the ash. The calcium in milk is partly in colloidal suspension and partly in true solution (p. 291). Probably about one-third is in solution and diffusible. Colostrum and late lactation milk are richer in calcium than normal milk.

The stability, and especially the heat and alcohol stability of milk is largely controlled by the proportion of phosphate and citrate to calcium and magnesium. Salt balance is thus of fundamental importance in the manufacture of evaporated and condensed milk (p. 284), the outstanding factor being the calcium-phosphate ratio. This ratio is influenced by breed of cow, stage of lactation, and season of the year, also possibly by mastitis and feeding. It is possible that changes in salt balance are associated with " May troubles " (p. 665).

Refs.: Davies; Richmond; Smeets and Seekles (1952), *N*, **169**, 802 (det. Ca ions in milk); Pyne (1949), *IDC*, **2**, 231; Pyne (1940), *JDR*, **11**, 292 (estimation of soluble Ca).

CALF. *See* Breeding ; Feeding ; Management of dairy cattle.

CALF STARTER. A special feeding stuff designed for young calves. Dried whey is normally a prominent constituent.

CALGON. A trade name for sodium hexametaphosphate $Na_6(PO_3)_6$ which forms soluble or non-adhering complexes with calcium and magnesium salts in hard water and so has a softening effect. This same property also makes the salt invaluable for cleaning plant from lime salt deposits. Condensed phosphates also act as anti-corrosion agents (Raistrick (1952), *CI*, 408). *See* Bottle washing ; Cleaning and sterilising ; Corrosion ; Detergents ; Water.

CALIBRATION. All volumetric glassware used in dairy laboratories should be calibrated, *i.e.* checked for accuracy and a correction applied if necessary. The most important apparatus in this respect is the Gerber butyrometer ; other equipment which should be calibrated includes the automatic measures for the acid and amyl alcohol, the burettes for titratable acidity, thermometers and lactometers.

Although the term " calibration " applies strictly to checking graduations, it must not be overlooked that the method or technique of analysis is a material factor in accuracy ; it is essential therefore to use the correct technique for calibration and subsequent analysis. The apparatus should also be calibrated over the whole of the working range.

It is customary to refer all analyses ultimately to a gravimetric standard, *e.g.* a volume of water may be weighed, or a well mixed sample of milk analysed for fat by the Röse-Gottlieb method. It is, however, permissible for routine purposes to calibrate one volumetric apparatus in terms of a known accurate apparatus, *e.g.* a calibrated burette. Care should be taken to distinguish between primary true calibration, *e.g.* checking a lactometer against a specific gravity bottle, and secondary calibration, *e.g.* checking a lactometer against gravimetric solids-not-fat and fat determinations. In the former case we are concerned only with specific gravity; in the latter with specific gravity and also an arbitrary formula which may introduce quite distinct errors.

The following table (Ca I) summarises methods of calibration in the dairy laboratory.

TABLE Ca I

Apparatus	*Factor measured*	*Primary or true gravimetric calibration*	*Volumetric calibration*	*Secondary gravimetric calibration*
Gerber butyrometer	Fat	Weighing mercury	Kerosene method, Day & Grimes (1918), *A*, **43**, 128; Dolby (1949), *JDR*, **16**, 334.	Against Röse-Gottlieb method
Automatic measures	Sulphuric acid Amyl alcohol	Weighing amount delivered		
Pipettes	Milk	Weighing milk		
Lactometers	Specific gravity	Against sp.gr. by sp.gr. bottle or Sprengel tube	Calibrated lactometers	
Thermometers	Temperature	Against ice in water and boiling water	Calibrated thermometers	
Thermometer (freezing point)	Freezing point of milk	Pure water and sucrose solutions* (7 to 8·5 %)		
Burettes	Volume of $\frac{N}{9}$ NaOH etc	Weighing water		
Pipettes	Volumetric reagents	Weighing water		

* Alternatively a N.P.L. calibration may be employed in conjunction with the ice point.

See Accuracy; Laboratories.

CALORIE. (i) *Small calorie.* The heat required to raise 1 g. of water 1° C. (ii) *Large calorie, calorie, kilocalorie,* or *food calorie.* This equals 1000 small calories.

The Calorie requirements of an average man vary from 2000 to 3500 daily according to his activity. Carbohydrates and proteins yield 4·1 Cals., fats 9·3 Cals. per g. Milk yields about 66 Cals. per 100 ml. *See* Economic nutritive values; Nutritive values.

CALORIFIER. An equipment for producing hot water by the injection of steam or similar means.

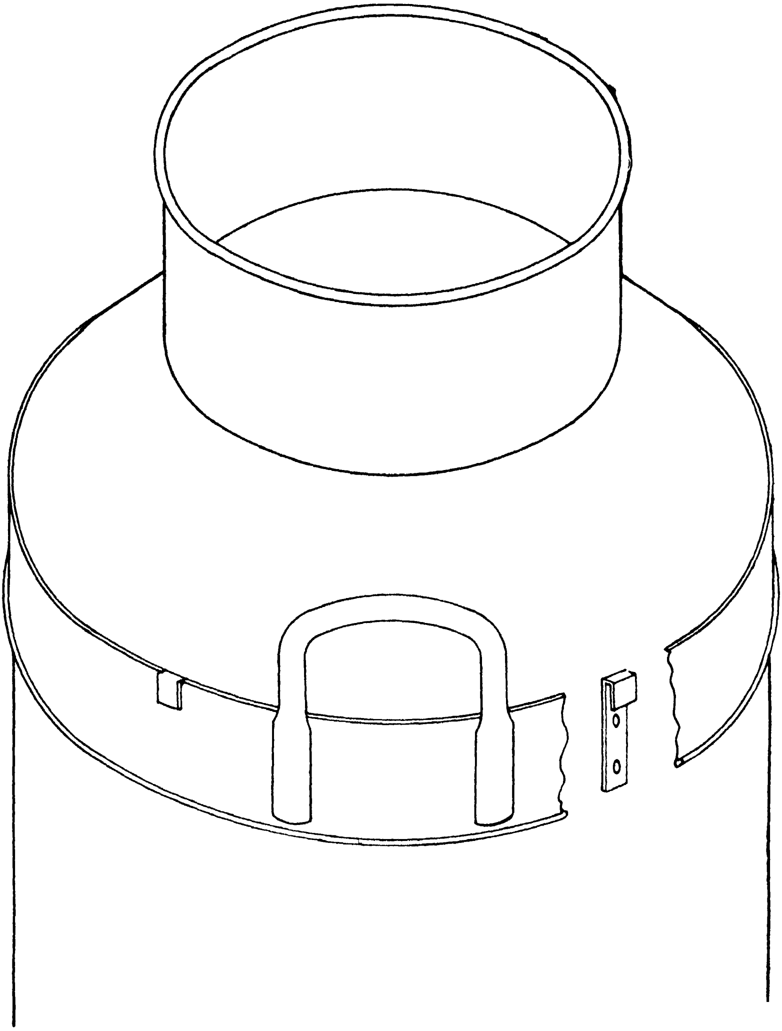
CALVES.

Refs.: Phillips (1952), *JDR*, **19**, 1 ; Phillips (1950), *JDR*, **17**, 1 ; Phillips and Davies (1949), *JDR*, **16**, 1 ; Phillips *et al.* (1949), *JDR*, **16**, 129.

CAMBRIDGE. *See* Cheese, p. 186.

CAMEL MILK. *See* Mammals.

CAMEMBERT. *See* Cheese, p. 186.



[*By courtesy of Dairy Supply Co. Ltd.*

FIG. Can 1.—*Arrangement of Top Hoop Retaining Key.*

CAMPBELL'S PROCESS. One of the early patented methods for drying milk in England (1901). Concentration was effected by hot air blasts, the milk being subsequently dried in a rotating drum and the pieces finally ground and sieved. The method is now virtually obsolete. *See* Milk powder.

CANADA.

Ref.: Derby (1949), *IDC*, **4**, 516; Innes (Editor) (1937), *The Dairy Industry in Canada*, London; Hood (1953), *DSA*, **15**, 1.

CANS. A common trade term for metal containers for milk varying in capacity from 1 to 17 gal. A recent development in can construction consists in the positive attachment of the top hoop (which usually has the can handles welded thereon) to the can body by means of " hoop keys ". These keys (usually four in number) are welded to the can body before tinning and are subsequently tinned, together with the body. The top hoop, tinned separately, is provided with notches which register with the hoop keys when the hoop is fitted into position. The hoop keys are then bent over and sealed with the usual solder fillet which normally is applied to the top hoop (Fig. Can 1).

The advantage of this construction lies in the fact that no difficulty is experienced in providing an adequate coating of tin between the top hoop and the body of the can and this is not always the case where hoops are welded to the body. Unless there is adequate tinning between these two parts there is always a danger of rust and corrosion occurring. While it is virtually impossible for the hoop to part company from the body through misuse or accident, nevertheless it is easily removed if required for retinning or other repair work.

The hand-can used for delivering milk by dipper or measure to the housewife's jug holds 1 or 2 gal., but has now been largely displaced by bottle delivery, and is seen only in use by smaller dairymen and in rural districts. The 1949 Regulations (p. 607) will result ultimately in the elimination of loose milk and hence the hand can. *See* Churns.

CANNED CREAM. *See* Cream, canned.

CANNING, CANNED FOODS.

Refs.: Jones (1949), *Canning practice and control*, London: Woodcock and Lewis (1938), *Canned Foods and the Canning Industry*, London ; Amer. Can Co. (1939), *The Canned Food Reference Manual*, New York ; Baumgartner; Gillespy (1951), *JSFA*, **2**, 107; (1953), **4**, 553.

CAPPING. *See* Bottle filling.

CAPRIC ACID. Capric or decanoic acid C_9H_{19} . COOH is one of the intermediate fatty acids, is volatile in steam, and imparts a characteristic peppery flavour to cheese (p. 168) made from goats milk (p. 490) in the fat of which it occurs to a greater extent than in cows' milk, hence the name (**caper** = goat).

CAPROIC ACID. Caproic or hexanoic acid C_5H_{11} . COOH is similar to capric acid but is less peppery in taste and more unpleasant to the smell.

CAPRYLIC ACID. Caprylic or octanoic acid C_7H_{15} . COOH is intermediate in properties to caproic and capric acids. *See* Fatty acids.

Ref.: Bloor.

CAPSULES (Bacterial). Certain types of bacteria have the power to enclose themselves in a jelly-like bag which prevents their taking the simple routine bacterial stains. The most common are *Leuconostoc* or *Streptococcus III* (Lactic acid bacteria) and some of the coli-aerogenes group (p. 262).

Ropiness (p. 932) in milk may be due to encapsulation by certain types of bacteria, usually derived from water in ponds, etc. Capsule formation is usually enhanced by low temperatures, and certain sugars, especially sucrose or cane sugar. The material of the capsules may be a gum (carbohydrate), a mucin (protein + carbohydrate) or both.

Refs.: Chalmers ; Cunningham ; Stephenson ; Wilson and Miles.

CAPSULES (Incubators and Water Baths). Constant temperature control for incubators and water baths may be obtained by bimetallic elements or capsules which consist of an organic liquid which " volatilises " at the temperature concerned and is held in a thin metal closed envelope. In the writer's experience the latter are more reliable.

CARAGEEN. *See* Stabilisers.

CARAMEL TAINT. A sweetish burnt sugar aroma usually due to the growth of an atypical *Str. lactis*. *See* Flavours; Malty taint.

CARAMELISATION. The browning of sugar solutions by heat. *See* Browning; Sterilised milk.

CARBOHYDRATES. One of the three important major groups of naturally occurring substances and containing only carbon, hydrogen, and oxygen. They are polyhydroxy-aldehydes and -ketones or more complex compounds which can be hydrolysed to these. They may be grouped as follows:

Monosaccharides .	(*a*) Pentoses $C_5H_{10}O_5$ (ribose, arabinose, and xylose, etc.). (*b*) Hexoses $C_6H_{12}O_6$ (glucose or dextrose, galactose, fructose, etc.).
Disaccharides .	$C_{12}H_{22}O_{11}$ (sucrose or cane sugar, lactose or milk sugar, maltose, etc.).
Trisaccharides .	$C_{18}H_{32}O_{16}$ (raffinose, etc.).
Polysaccharides .	$(C_6H_{10}O_5)_x$ (starch, glycogen, dextrin, cellulose, gum, etc.).

Certain enzymes and hot acids hydrolyse or split up the more complex carbohydrates to simpler ones, *e.g.*

$$\text{lactose} \xrightarrow{H_2O} \text{glucose} + \text{galactose}$$

$$\underset{\text{starch}}{(C_6H_{10}O_5)_x} \xrightarrow{H_2O} \underset{\text{glucose}}{x(C_6H_{12}O_6)}$$

Carbohydrates are of importance as one of the main sources of energy in foods (*see* Nutritive value), and are also of interest biologically in relation to vitamin C (p. 1061), ropiness in bacterial cultures (p. 162), various fermentations producing lactic and acetic acids, carbon dioxide, alcohol and various aldehydes and ketones. Some of these are of importance in relation to the production of flavour in dairy products (p. 471). *See* Glucose; Lactose.

Refs.: Prescott and Dunn; Stephenson; Tyler; Bell (1952), *Introduction to Carbohydrate Biochemistry*, Hudson *et al.* (ed.) (1951), *Advances in Carbohydrate Chemistry*.

CARBOLIC TAINT. *See* Stability; Sterilised milk.

CARBON DIOXIDE. This gas CO_2 represents the complete oxidation of carbon, and is produced by all living things from viruses and bacteria up to man. From the dairying point of view, the most important aspects are the consumption of the oxygen in milk, etc., by bacteria with the consequent production of CO_2, the retardation of reactions, whether desirable or undesirable, which involve free oxygen, the slight decrease in *p*H due to the weak acid reaction of the CO_2 and the attractive taste which CO_2 gives to foods, *e.g.* in fermented milks (p. 566) (Kefir). In some cases, however, concentrated CO_2 gives a peculiar "cold" taste, *e.g.* in butter freshly produced by the Senn process (p. 154).

High pressures of CO_2 have been used to kill bacteria and so preserve dairy products in an unobjectionable way, but it appears that violent *changes* of pressure are necessary, high pressures as such having little effect.

Milk in the udder contains about 10 per cent. by volume CO_2.

CARBONATION. The treatment of liquids with carbon dioxide, especially under pressure. Carbonation usually improves taste and aroma, lowers the *p*H slightly, and has only a slight effect on keeping quality.

CAROTENE. A yellow-red fat-soluble pigment which gives most of the yellow colour to milk and butter. Channel Island breeds give milk containing relatively more carotene and less vitamin A than Shorthorn milk. Its formula is $C_{40}H_{56}$ and it is the precursor of vitamin A. *See* Nutritive value; Vitamins.

CAROTENOIDS. A general name for the carotene type of pigment. Carotene is the chief carotenoid in milk, xanthophyll (lutein) also being present. *See* Vitamins.

Refs.: Goodwin (1952), *The Comparative Biochemistry of the Carotenoids*, London; Palmer (1922), *Carotenoids and Related Pigments*, Chemical Catalogue

Inc. ; Rogers ; Kieferle and Seuss (1949), *M*, **4**, 351 ; Kon and Henry (1949), *JDR*, **16**, 68 ; Sutton *et al.* (1947), *JDS*, **30**, 927 ; Trout *et al.* (1943), *JDS*, **26**, 495 ; Gillam and Kon (1940), *JDR*, **11**, 266.

CARTONS. Cartons are usually made of cardboard impregnated with paraffin wax and are probably the ideal container for milk, being very light, virtually sterile because of their mode of manufacture and non-returnable. In addition they can be made square, thus simplifying packing and economising in space. Their one disadvantage is their relatively higher cost.

The following note (*Dairyman* (1947), **64**, 105), summarised the economic aspects of the carton idea at that time:

> A strict and accurate comparison between glass and paper will never be known until actual figures for twelve months are available for any size of dairy using a carton system.
>
> It is suggested that the following points might usefully occupy the mind of a prospective purchaser of a carton plant :
>
> (1) The price of the special paper used is at present twice its pre-war cost and is considered to be weighted by Paper Control. A demand from the dairy trade would, in my opinion, reduce the price by at least 25 per cent., or alternatively result in an increase of the distributive margin while paper prices are finding their post-war level.
>
> (2) Although rationalisation still exists and there is no free sale of milk, it is suggested that it would be very unwise for the dairyman to accept that this will always be the position. It has been stated that strict economics will always be the governing factor as between bottle and carton systems. Is this strictly correct ?
>
> No member of the trade would suggest for one minute that glass bottles, when they were first introduced into the trade, were cheaper than the old system of tin cans, or dipping out of the open churn ; in fact they were very much dearer. Progress, however, would not be denied and glass bottles took on in spite of the economics of the situation. It is claimed that carton packing is more hygienic and, therefore, further progress on the road to efficiency. It surely cannot be very far distant when carton packing will be recognised by the Ministries of Health and Food as progress in the right direction, and help will be given to the trade to bring it about. This, plus competition for business when free markets are once again in force, is, we think, sufficient reason for the dairyman to take a long-term view of carton packing even now.
>
> (3) I am further of the opinion that the larger the dairy, the bigger the saving which can be effected by the substitution of paper for glass, and particularly in the case of large wholesale bottle milk trade delivered to customers where the saving in transport would be very great.
>
> In a large business of many thousands of gallons per day, carton machines of a much larger capacity than the 2000 cartons per hour of the present size would be used with lower capital and operational costs per 1000 cartons.
>
> (4) Before the era of food rationing, large quantities of groceries, etc., were sold by dairy roundsmen, and this state of affairs will probably obtain again in due course. It is obvious that if a roundsman is not concerned with the collection of empties he could take out and sell more milk and other commodities.

CAPITAL EXPENDITURE

		Glass			*Cartons*
Filler and aluminium capper		£2,000	(Filler only)		£500
24,000 pint bottles at 36s. per gross		300			—
Bottle washer		800			—
Carton machinery		—			4,500*
1,200 × 20 pint crates at 10s. each		600	at 5s.		300
Delivery vehicles :					
5 Road vans	£2,250		3 Vans	£1,350	
5 Electric prams	1,150		5 Prams	1,150	
	———	3,400		———	2,500
Balance in favour of glass		700			—
		£7,800			£7,800

* Minimum running life ten years.

PACKING COSTS PER ANNUM

	Glass		*Cartons*	
		P.P.G.		P.P.G.
Bottle replacements on a basis of 20 journeys per bottle	£1,800	1·184	—	—
Paper consumption : 82 tons at £60 per ton, glue, etc.	—	—	£4,986	3·278
Aluminium capping and bottle breakage under capper, upkeep of capper, etc.	380	0·250	—	—
Wages, washing and filling : 2 men at £6 ; 2 assistants at £3 = £18 per week . . .	936	0·615	—	—
Carton making and filling : 1 man at £6 ; 3 assistants at £3	—	—	780	0·513
Sundry expenses	150	0·099	75	0·050
Power	150	0·099	65	0·043
Repairs and renewals	100	0·066	50	0·033
Rent, rates and insurance	150	0·098	125	0·082
Crate replacements	60	0·039	30	0·020
	£3,726	2·450	£6,111	4·019

DISTRIBUTIVE COSTS

		P.P.G.		P.P.G.
Wages :				
10 roundsmen at £6 per week	£3,000	1·973 (8R)	£2,400	1·578
Operational cost of 5 road vehicles and 5 electric prams	2,730	1·795 (3V) (5P)	1,625	1·068
	£5,730	3·768	£4,025	2·646

SUMMARY OF CAPITAL COST AND DEPRECIATION

If a 10-year period is taken and the whole of the capital expenditure on both systems is written off, the final result would be as follows :

	Glass	*Cartons*
To Capital written off in first 5 years at 20 per cent. per annum	£7,100	—
,, Capital written off in second 5 years at same rate . .	7,100	—
,, Capital written off in 10 years	—	£4,500
,, Capital written off twice in 10 years at £3,450 for 5-year period	—	6,600
,, Higher operational expenses at 0·040 per gal.	—	620
By Balance in favour of Cartons	—	2,480
	£14,200	£14,200

The average saving over ten years is therefore £264 per annum or 0·174d. per gal. (However, it must be borne in mind that prices have risen considerably in the last seven years. Prices would now be about double those quoted. They should be regarded only as an example of one method of approach to the problem. Modern types of cartons are illustrated in Fig. Car 1, and a carton making machine in Fig. Car 2. The limiting factor in retail milk distribution is time rather than weight.)

REMARKS

In the above figures it is considered that the following depreciation figures apply :

Glass bottling machinery .	20 per cent.	per annum	completely	renewable	in	5 years.
Road vehicles and barrows	20 ,,	,,	,,	,,	,,	,,
Carton machinery . .	10 ,,	,,	,,	,,	,,	10 ,,

See Bottle filling ; Costings (p. 314).

CASEIN. The chief protein in milk, to which it is peculiar. It is a complete protein, containing all the essential amino acids, and occurs in milk as a colloidal suspension associated with calcium phosphate. It is altered and precipitated by rennet, the change being described as caseinogen → casein, or casein → paracasein.

The elementary composition of casein is :

	%
Carbon	53·50
Oxygen	22·14
Nitrogen	15·80
Hydrogen	7·13
Phosphorus	0·71
Sulphur	0·72

TABLE Cas I

AMINO ACID COMPOSITION OF CASEIN

(Eilers *et al.*)

Amino acid	*Percentage in casein*	*Percentage of total nitrogen*
Glutamic acid	21·8	13·2
Arginine	4·4	9·0
Lysine	7·2	8·7
Leucine	12·1	8·2
Histidine	3·7	6·3
Proline	8·0	6·2
Alanine	5·6	5·6
Valine	7·2	5·4
Serine	5·2	4·3
Tyrosine	6·4	2·9
Aspartic acid	4·1	2·7
Threonine	3·5	2·6
Phenylalanine	3·9	2·1
Methionine	3·2	1·9
Oxyproline	2·1	1·4
Tryptophane	1·4	1·2
Iso-leucine	1·4	1·0
Glycine	0·5	0·6
Diaminotrihydroxydodecanic acid	0·75	0·4
Cystine	0·4	0·3
Ammonia	1·6	0·3
n-Valine	0·2	0·2
Citrulline	trace	trace
Phosphoric acid	2·7	0·0
Galactose	0·3	0·0

The total percentage by weight exceeds 100 because the linkage in the casein molecule eliminates water.

Casein is precipitated by acids, the isoelectric point being at *p*H 4·6. One gram of casein will combine with 9 ml. 0·1 N alkali or 7 ml. 0·1 N acid. *See* Constituents; Amino acids; World production.

Refs.: Eilers *et al.*; Sutermeister and Brown (1939), *Casein and its Industrial Application*, New York; Beau, *La Caseine* (1932 33), Paris; Tague (1926), *Casein: Its Preparation, Chemistry and Technical Utilisation*, London; Davies; Richmond; Rogers; Chem. Reviews, *JDR;* B.S. 1416 (1948) (analysis rennet casein); B.S. 1417 (1948) (analysis acid casein); Hipp *et al.* (1952), *JDS*, **35**, 272 (Sep. of α-, β- and γ-casein); Hostettler and Imhof (1951), *M*, 351, 400; (1952) LJS (N.S.) **1**, 307 (particle structure); Hostettler and Rychener (1949), *IDC*, **2**, 175.

CASEIN NUMBER. The percentage of nitrogen in milk present in the casein. Rowland has developed this as a chemical test for mastitis. *See* Abnormal milk; Casein; Mastitis; Testing of milk supplies.

Refs.: Rowland (1938), *JDR*, **9**, 47; Rowland and Zein-El-Dine, *ibid.*, 174.

CASEIN PLASTICS. Plastic materials formed by condensing casein with formaldehyde, etc.

CAT MILK. *See* Mammals.

CATALASE. An enzyme present in almost all living cells which decomposes hydrogen peroxide to water and molecular (inactive) oxygen. Milk itself contains very little catalase, but a high cell content due to mastitis (p. 659) results in a high catalase value.

CATALASE TEST. *See* Lactic acid bacteria; Mastitis.

CATALYSTS. Catalysts may be defined as substances which can accelerate or bring about a chemical reaction without themselves undergoing permanent change. *See* Auto-oxidation; Copper; Enzymes; Flavours.

CATAPHORESIS. The movement of charged particles in a liquid towards the electrodes under the influence of a direct current. *See* Anions; Cations.

CATHODE RAY TREATMENT. *See* Pasteurisation, alternatives to.

CATIONIC AGENTS. A general term for those substances in which the positively-charged radicle is responsible for the bactericidal or other property. The quaternary ammonium compounds $R_1R_2R_3R_4Na^+$ Br^- (p. 879) are an important example. *See* Detergents.

CATIONS. Ions bearing a positive charge, *e.g.* Na^+, Ca^{++}, Al^{+++}. *See* Anions.

CATTLE. *See* Breeding; Feeding; Management of dairy cattle.

CAUSTIC SODA. Sodium hydroxide, NaOH, the caustic constituent of bottle-washing detergents (pp. 103 and 367). Also called *lye*.

CAVITATION. The formation of minute bubbles of gas or vapour. It appears that cavitation may be a factor in the homogenising and emulsifying effects of ultrasonic vibrations, and possibly in mechanical homogenisation.

Ref.: Loo *et al.*, (1950), *JDS*, **33**, 692.

CELLS. *See* Body cells.

CENTIGRADE. *See* Thermometric scales.

CENTIMETRE. 0·3937 in. *See* Weights and measures.

CENTRIFUGE. Any machine which rotates containers of liquids at a high speed. *See* Fat; Separators.

CEREAL. A grass producing edible grain. *See* Feeding.

C.G.S. The centimetre-gram-second or metric system of units.

CERTIFIED MILK. An abbreviation for the former designation, Tuberculin-Tested (Certified). It is now termed Tuberculin tested (Farm bottled) milk. *See* Designated milks; Legal aspects; Tuberculin-tested milk.

CHAIN REACTION. (i) In biology a sequence of reflex actions. (ii) In chemistry a sequence of chemical reactions. In both cases any one reaction is dependent on the previous one.

CHANNEL ISLANDS BREEDS. These include Jersey, Guernsey, and Alderney, the last being rare. *See* Breeding; Legal aspects; Management of dairy cattle; Milk marketing; Quality payment.

CHANNEL ISLANDS MILK. This is now defined as milk from Channel Islands cows and containing at least 4 per cent. fat. It commands a premium of 4d. per gal., the consumer paying an extra 8d. per gal. *See* Quality payment.

CHARACTERISTICS OF MICRO-ORGANISMS. This term refers to those properties used for identification and classification purposes (p. 229).

CHECKER. A dairy operative who examines, usually by smell, each churn of incoming milk for freedom from taint and souring. The volume is, of course, also checked, or the milk weighed. The term is also sometimes used for an operative who checks bottles and milk in a pasteurising depot. *See* Management of creameries; National Milk Testing Scheme; Platform testing.

CHEDDAR. *See* Cheese, p. 171.

CHEESE. It is probable that cheese was made accidentally in the first instance by the carrying of milk in the stomachs of animals, when the milk-clotting enzymes of the stomach converted the liquid milk into a solid mass or junket.

Doubtless it was soon found that cheese, although crudely made, possessed much better keeping qualities than the original milk and so provided foods suitable for journeys. It was thus early recognised that cheesemaking is a convenient method of converting a considerable part of the constituents of milk into a product that will keep well, is less bulky as it contains much less water, is of high nutritive value, and is both palatable and readily digestible.

Practically all cheese names are geographical, so that the reason for naming might appear obvious. In the case of Cheddar, however, there is no evidence that the best cheese ever came from Cheddar itself, and it is probable that visitors to the famous gorge and caves took away the local cheese, which thus became known far and wide as Cheddar cheese.

The factors which have controlled the survival of present-day varieties are: keeping quality and transportability; standardisability; ease of manufacture; palatability and requirements for special markets. Examples of the influence of special markets are the soft short-keeping Caerphilly which, being high in moisture and salt, is popular with the miners of Wales, and the very long-keeping Parmesan, which is sometimes kept for ten years or more and is dispensed with the aid of chisel and mallet.

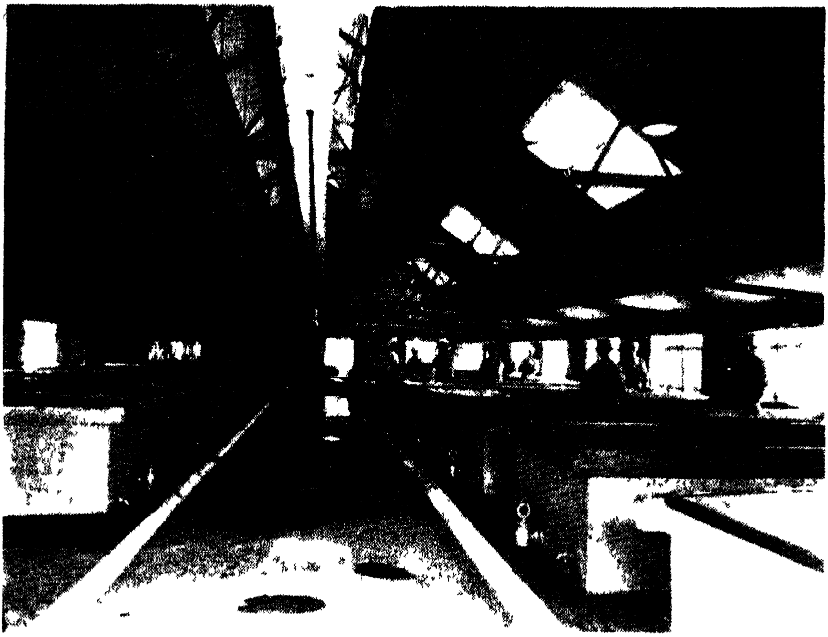
There is little doubt that Cheddar and Cheshire have survived as our most important English varieties because of their good keeping qualities and ability to " travel ".

The more important cheese names now have no regional significance at all. Thus not only is Cheddar made all over the British Isles but in New Zealand, Canada, United States, Australia, and even in Germany. Cheddar cheese is probably the best known in the world. Many variants are now recognised, such as American, New Zealand, and Canadian Cheddar. Scotch Cheddar is a somewhat harder, and Dunlop a somewhat softer variant of Cheddar cheese.

Cheesemaking is mainly a seasonal industry, and a proportion of the summer surplus of milk in the dairying regions is converted to cheese. Cheesemaking is thus largely confined to the heavy milk-producing areas, especially those at some distance from the milk-consuming urban localities. In England these areas are Somerset, Devon, Wilts., Dorset, Cheshire, Shropshire, Lancashire, and Yorks., together with areas in Wales and the Midlands. In Scotland, cheese is made mainly in Ayrshire, Wigtown, and Kirkcudbright.

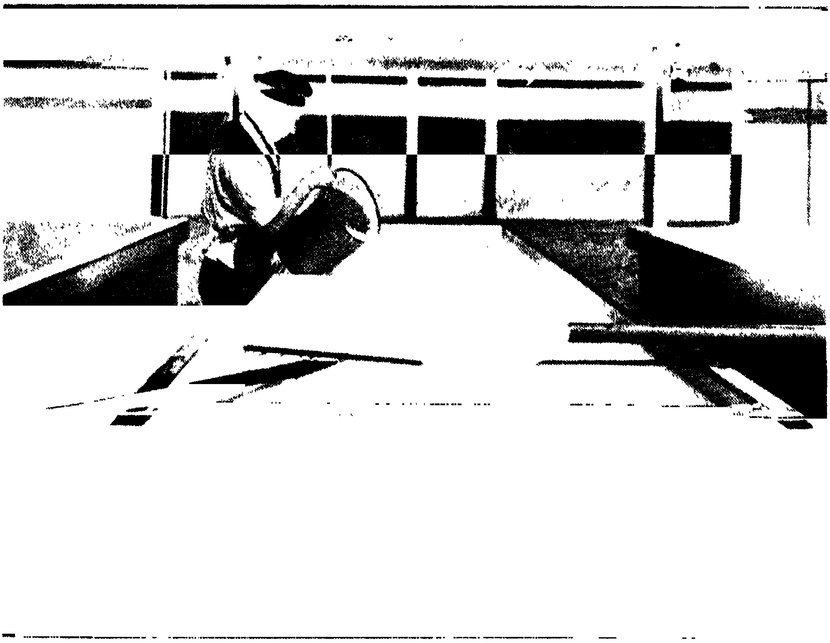
Until about 1850 all cheese were made in farmhouses, but from 1850 onwards the modern factory system of cheesemaking was developed in America and the first English cheese factory was opened in 1871 at Derby. Farmhouse cheesemaking continued to flourish until the last war, after which it steadily declined for a number of reasons. The founding of the Milk Marketing Board, which ensured a guaranteed price for milk, was one of the biggest factors, and in the last decade factory cheesemaking has increased considerably and farmhouse cheesemaking declined. Much as we may regret it, it is probable that farmhouse cheesemaking is a doomed industry, and that only a few of the finest craftsmen will survive. The growth of the factory system naturally encouraged those methods which could be standardised and reproduced from day to day, and this is one of the reasons for the present popularity of Cheddar. All methods of cheesemaking are to some extent uncertain, in that the exact behaviour of the milk and curd can never be predicted, but Cheddar is less subject to this uncertainty than most.

The American factory system was later adopted in Scotland, where it was known as the Canadian system. Two other systems, known as the Candy and Cannon systems, were also recognised in 1890. The former, perfected by Mr.



[*By courtesy of United Dairies Ltd.*

FIG. Ch 1.—*Cheddar Cheese Factory.*

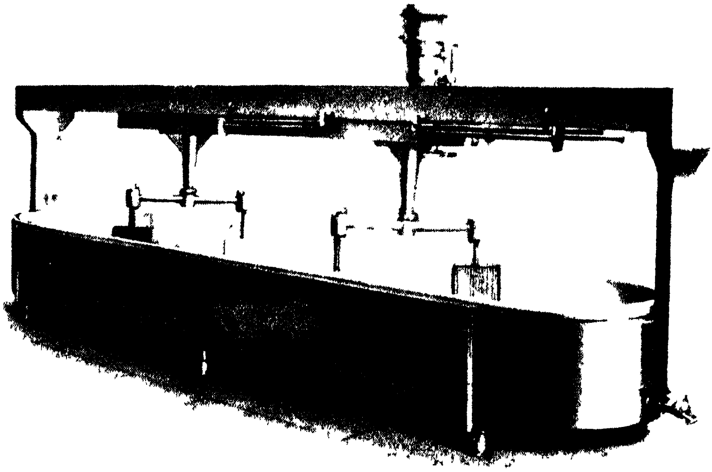


[*By courtesy of United Dairies Ltd.*

FIG. Ch 2.—*Adding Rennet.*

[By courtesy of United Dairies Ltd

FIG. Ch 3 – *Cutting the Coagulum.*



[By courtesy of Huon & Rempler Ltd

FIG. Ch 3A —*Cheese Vat with two Mechanical Agitators*

T. C. Candy, of Cattistock, in Dorset, and the latter, taught by Mr. Henry Cannon, of Milton Clevedon, Evercreech, Somerset, are both described by Lloyd (1899) in his report on " Cheddar Cheesemaking " to the Board of Agriculture.

It was early recognised that the many different ways of making Cheddar cheese all yielded much the same product.

In brief, cheesemaking consists in clotting milk by rennet, cutting the resultant junket or curd into small pieces and driving some of the whey out from the pieces of curd by the combined effect of heating and acid development, the finished material being packed into a metal or wooden container which determines the shape.

Very slight treatments will result in a soft, moist cheese of short keeping quality, and intensive application of heat, acidity, etc., will yield a hard, dry cheese that will keep for many months or even years. Thus we may consider ordinary junket (which is really a stillborn cheese) as one, and Parmesan cheese as the other extreme of a theoretically infinite number of varieties of cheese.

Table Ch I summarises the cheesemaking process and describes briefly what happens in each of the stages of manufacture.

TABLE Ch I

	Chemical and other changes in cheesemaking	*Cheesemaking terms*
(1)	Lactose (milk sugar) $\xrightarrow{\text{lactic streptococci}}$ lactic acid	" Ripening," souring, or acid development
(2)	Casein (in colloidal suspension) $\xrightarrow[\text{and acid}]{\text{rennet, heat,}}$ casein (denatured)	Clotting, coagulation, or setting
(3)	Denatured casein $\longrightarrow$ precipitated casein (= coagulum)	
(4)	Coagulum cut into small pieces	Cutting
(5)	Casein particles in curd draw together (model : contraction of spiral springs in vaseline) and so whey squeezed out of curd (= syneresis) (accelerated by heat, acidity, and fineness of cutting)	Drying out of curd by "scalding (cooking), increasing acidity and stirring
(6)	Curd allowed to fall to bottom of vat (begins to matt) and heaped together (now resembles sorbo rubber)	Pitching
(7)	Whey run out of vat	Whey off
(8)	Curd cut into blocks and piled up, Combined effect of rennet, acid, and heat changes casein so that matting proceeds rapidly and curd becomes more homogeneous (closer in texture)	Piling or cheddaring, 1st turn, etc.
(9)	Curd gradually changes from rubbery material to a silky, dough-like substance ultimately approaching a condition like chicken-breast meat in that it can be torn into leaves	Mellowing
(10)	Curd finally cut into small pieces (milled), salt added (the brine dissolving some of the protein) and the salted curd tightly packed into hoops or moulds	Milling (grinding) and salting.
(11)	Cheese put under pressure	In press
(12)	Cheese trimmed, washed, greased, and bandaged.	Dressing (press room work)

The finer points in cheesemaking are to be found in the skill with which the cheesemaker co-ordinates the factors under his control with those that may be out of his control.

In the various methods of cheesemaking not only are the different treatments modified over wide ranges but some treatments may be omitted entirely. If we classify the main types of cheese according to their method of manufacture, we can distinguish about twenty types of cheese, as described in Table Ch II. More than 400 named varieties are officially recognised, but these can all be classified

TABLE Ch II

METHODS OF MAKING—SUMMARY OF FUNDAMENTAL CHEESE TYPES

(Davis and Dearden 1937)

			Milk		Method of coagulation		Cutting			Scalding				Drainage		Salting			Shaping		
Type	Cheese variety	Characteristics	Skimmed	Ripened	Acid	Rennet	Ladled	Large	Small	None	Low	Med	High	Vat	Hoop	Curd	Cheese	Brine	Hoop	Hand	Pressure
Hard	Parmesan	Extremely hard																			
	Emmenthal	Large gas holes																			
	Cheddar	No gas holes																			
Semi-hard	Port du Salut	Fairly firm—mild flavour	( )																		
	Brick	Fairly strong sweetish flavour																			
	Pecorino	Sheep's milk																			
	Edam	Fairly firm																(or)			
	Gouda	Mellow																			
	Cacciocavallo	Full flavour—long keeping	( )																		
Soft	Limburg	Strong flavour bacterial ripening	( )																		
	Camembert	Strong flavour external mould ripening																			
Mould-ripened (blue veined)	Roquefort	Peppery flavour internal mould ripening																			
Acid coagulated	Cottage	Soft lactic flavour																			
	Sapsago	Flavoured by herbs																			
Cream	Cream	Made from cream																			

as variations of about twenty distinctive types. Thus over 200 varieties of soft cheese are reported to be recognised in France, but the names of most are of only local significance. Deprived of label and shape, experts would be unable to identify such cheese. Moreover, the variants of any one variety, such as Cheddar, often exhibit greater differences between themselves than can be detected between two named varieties, *e.g.* Cheddar and Gloucester.

For the purpose of studying cheesemaking we can conveniently consider the Cheddar process, as not only is Cheddar the best known and most important, but its manufacture involves nearly all the recognised treatments of milk and curd.

Cheesemaking. (i) ***Treatment of the milk.*** It is usual to make cheese from mixed evening and morning milk. Evening milk is less in quantity but much richer in fat. The percentage of fat in milk has a marked effect on the quality of the cheese, a high fat milk giving a soft velvety curd and a low fat milk a hard leathery cheese. Prizewinning cheese may be made from evening milk only or even with milk to which cream has been added. The latter device is sometimes used for certain varieties such as Stilton. Cream cheese, as the name implies, are made from cream. Some varieties are always made from skim milk (*e.g.* Cottage) or partly skimmed milk (*e.g.* Edam).

Although cow's milk is almost universally used in this country, the milk of most mammals can be made into cheese of one sort or another, and in some countries the milk of sheep, goats, etc., is commonly used. Thus, the classical French Roquefort was made from sheep's milk and the word " goat " has given its name to some varieties in France, Germany, and Italy. The increased demand for some of these (*e.g.* Roquefort) has led to the practice of using a mixture of sheep's and cow's milk, or even of cow's milk only. True cheese cannot be made from materials other than milk, but whey, soya flour, and other materials are sometimes used to give products resembling cheese.

The growth of the factory system (Fig. Ch 1) has inevitably affected the treatment of the milk for cheesemaking. Control of milk production is impossible and the milk has to be treated as soon as it arrives. Bulk milk is naturally more uniform chemically but is nearly always inferior bacteriologically to a farmhouse supply. In hot weather bulk milk used for factory cheesemaking usually has a count of the order of 10,000,000 per ml. It is not surprising, therefore, that in most factories the milk is now pasteurised in order to kill taint-producing micro-organisms, regularise starter growth and to yield a uniform product. In the early days the term " pasteurisation " covered a variety of heat treatments, most of them uncertain. Since excessive heat treatment (*e.g.* more drastic than 30 min. at 145 F.) affects the rennet clotting of the milk, and probably kills organisms responsible for the production of some of the characteristic flavours, it is not surprising that it was for many years commonly stated that " good cheese cannot be made from pasteurised milk ". Proper control of the pasteurising process has shown that this was a fallacy and that " flashing " (heating for a few seconds to 162° F.) or " shocking " (heating to 150° F. for 15 sec.) will give milk that behaves quite normally in the vat and yields a better and more uniform cheese. Raw milk naturally gives a stronger-flavoured cheese and its higher bacterial count results in more rapid ripening.

(ii) ***Acid development (souring or " ripening ").*** Acidity is one of the major factors in cheesemaking, both in the actual clotting of the milk and in the mellowing of the curd. A slight development of acidity is necessary in order to permit the formation of a workable rennet clot. Originally cheesemakers relied on the naturally developed acidity of the milk, as in practice milk is always contaminated with acid-producing bacteria, but in the last thirty years the use of milk cultures of lactic streptococci, known as " starters ", has become practically universal. The preparation and maintenance of starters is now an important and highly specialised part of cheesemaking and should be under the control of the laboratory. Failure of the milk and starter to develop acidity leads t most serious troubles. Not only is the whole cheesemaking timetable upset, but " slow starter ", as the fault is called, frequently results in a weak curd, high moisture, and taints in the cheese. When only one or two vats in a factory are affected the trouble is probably due to the milk, which may be chemically abnormal on account of a high proportion (*e.g.* over 15 per cent.) of mastitis milk, or may contain large numbers of bacteria inhibitory to the acid-producing starter streptococci. If all vats are affected, it is obvious that the starter itself is at fault and the reason is almost certainly *bacteriophage*, an ultramicroscopic material that destroys the lactic streptococci. Slow starter is economically the most important fault in the cheese industry. *See* Starters.

Early cheesemakers estimated the acidity by rule-of-thumb methods, such as smell and the rennet test, but in 1891 Lloyd introduced the well-known acidity test, which is simply the ordinary chemical method for titrating the strength of acids. Typical acidities for some varieties of cheese are given in Table Ch III.

TABLE Ch III

TYPICAL ACIDITIES IN CHEESE MANUFACTURE

(as per cent. lactic acid)

	Cheddar	*Cheshire*	*Derby*	*Lancs.*	*Caerphilly*
At renneting . .	0·20	0·22	0·19	0·18	0·22
After cutting . .	0·14	0·14	0·12	—	0·14
At pitching . . .	0·17	0·16	—	—	—
Whey off . . .	0·20	0·19	0·15	0·13	0·16
First cut or break .	0·26	0·25	—	0·14	0·20
Milling . . .	0·85	0·70	0·47	0·90	—
From press . . .	1·00	—	—	1·15	—

Cheesemakers commonly use 3 drops of phenolphthalein in 10 ml. of milk or whey (*see* Acidity, titratable, technique for). These values will therefore be 0·02 higher than if measured by the new technique.

It is now accepted that the real factor controlling curd behaviour is *p*H or hydrogen ion concentration. This factor can be measured by coloured indicators or electrical *p*H meters. This method of control is already used commercially in America and in Germany, and there is little doubt that ultimately all factory cheesemakers will employ *p*H control methods.

During cheesemaking, measurements of acidity are continually being made, but these do not permit anyone to make good cheese. Considerable experience and skill are needed in the interpretation of the acidities according to the type of milk, season of the year, rate at which the acidity is developing, and the type of cheese required. Not only does acidity control moisture, but moisture also controls acidity, as this can only form from the lactose in the whey, and the more whey in the curd the greater the potential acid. Moreover, the amount of free moisture controls the rate of bacterial growth.

If the acidity races away because of a very vigorous starter, or dirty milk, or hot weather, the cheesemaker has to modify the various operations to keep pace with the acidity. Success depends largely on the skill with which a proper balance can be maintained between acidity and moisture in the curd. These are two constantly changing factors which influence each other.

After the starter has been thoroughly mixed in, the temperature of the milk is raised to the renneting temperature, for Cheddar about 85° F., and the milk stirred at intervals until sufficient acid has developed for renneting. The renneting acidity is one of the crucial points in cheesemaking. If the acidity is too high drainage will be difficult, the curd will retain moisture and leak whey after a few days. If the acidity is low, the curd will be hard and appear dry but will release moisture after a few weeks. The other crucial stages are: (ii) pitching the curd, (iii) running off the whey, and (iv) milling and salting.

(iii) ***Renneting.*** When the correct acidity has been reached, rennet is added at the rate of about 1 ml. per gal. of milk (one part in 4500) (Fig. Ch 2). The mechanism of clotting is not yet completely understood, but recent work by Berridge suggests that rennet acts by denaturing (or destabilising) the casein. This then precipitates in tiny particles which, instead of falling to the bottom of the milk, remain lightly attached to each other so that the milk becomes a jelly or junket.

All proteolytic enzymes can clot milk, and we have made experiments with other proteolytic enzymes, but in no case has any one proved as good as rennin. It seems that the special virtue of rennin lies in its high ratio of clotting power to protein-digesting ability. Cheese ripening is essentially a very slow digestion, and anything which results in rapid digestion, such as high temperatures, very dirty milk, and powerfully proteolytic enzymes, also results in unpleasant flavours and faulty cheese.

The rate at which milk clots depends chiefly on the acidity and temperature. Usually it requires about ten minutes, and the milk must be carefully " surface stirred " nearly up to this point. When the coagulum is properly set and " breaks cleanly " with the finger it is ready for cutting. Scott Blair has devised an apparatus which measures the elasticity of the curd and can be used to determine the correct time for cutting.

(iv) ***Cutting the curd.*** In the old days a " breaker " was used for cutting Cheddar curd, but American knives which resemble gridirons with sharp edges are now used. A knife with vertical blades is moved horizontally through the curd, first along the vat and then across it (Fig. Ch 3). Next, one with horizontal blades is used in the same way, with the result that the coagulum becomes a mass of tiny pieces of very soft curd about the size of a pea floating in a yellow-green whey. The rate of drainage of whey from these pieces of curd is accelerated by fineness of cutting and by acidity and heat. Stirring may be mechanical (Fig. Ch 3*a*).

(v) ***Scalding or cooking.*** As soon as the cutting has been completed the sides of the vat and tap are cleared and steam is applied to the outer jacket at such a rate that the temperature rises to 90° F. in about 15 min. and then to the maximum scald temperature (95° to 110° F.) at the rate of 1° every 2 min. If the temperature is raised too rapidly a condition similar to " case-hardening " will be produced, and the curd will be hard on the outside but soft and " waterlogged " in the interior. Of all faults in cheesemaking retention of moisture is the worst as it leads to leaky cheese, weak body, and the development of discoloration and taints. The actual temperature chosen depends on many factors, particularly the type of cheese required and the time of the year. Low scalding temperatures leave more moisture in the curd and so give a softer cheese; high temperatures give a drier, harder curd which results in a long-keeping cheese. In addition, high temperatures affect the protein and give a more rubbery or springy curd, *e.g.* as in Emmenthal cheese (Table Ch IV). Both curd and cheese exhibit viscous flow and elastic recovery. *See* Rheology.

(vi) ***The pitching point.*** When the maximum scald temperature has been reached the stirring is continued until the curd has reached the condition suitable for " pitching ", or settling at the bottom of the vat. This is one of the most important operations in the process and is related not only to the moisture content but also to the physical condition of the curd, particularly its " mattability ". Cheesemakers have different methods for determining when the curd is ready for pitching, but one of the most useful is to move the hand backwards in the whey, when the curd produces a peculiar tingling or " shotty " effect on the skin. Scott Blair and Coppen have devised an ingenious and simple method for following the physical condition of the curd (actually the superficial density).

(vii) ***Piling the curd.*** When the correct acidity has been reached the curd is pushed up to one end of the vat (with wooden rakes in the factory) and the curd mass, which now resembles sorbo rubber, cut in two and one half floated on top of the other. After a short time the whey is then run off through the tap (Fig. Ch 4). In the large factory vats of 500 or 1000 gal. the removal of the whey is sometimes a serious mechanical problem, and delays in this operation have undoubtedly been responsible for some bad cheese. It is now generally accepted that of all the operations this is the most crucial, and early cheesemakers have also emphasised this fact. The curd is next cut into blocks of convenient size (Fig. Ch 5) and these are piled up, in farmhouse making with a cloth in between the layers to facilitate drainage. The method of treatment of the curd during piling or cheddaring varies from place to place but always involves further cutting, turning, and piling to a greater height. A weight is placed on top to assist drainage.

TABLE Ch IV

PHYSICAL PROPERTIES OF DIFFERENT VARIETIES

Variety	*Type*	*Moisture*	*pV* (*Viscosity factor*)	*pM* (*Elasticity factor*)	*pS* ("*Springiness*" *factor*)	*Keeping ability*
"Convalli"	Soft	59.06	7.3	5.6	1.7	Few months
Little Dutch	Soft	46.27	-	5.7	—	Few months
Port du Salut	Soft	44.98	7.1	5.7	1.4	Few months
Bel Paese .	Soft	42.72	—	5.6	-	Few months
Lancashire .	Semi-hard	—	7.3	5.5	1.8	Few months
Leicester	Semi-hard	39.62	7.5	5.7	1.8	Few months
Pont l'Evêque	Semi-hard	39.24	-	5.7	—	Few months
Cheshire .	Semi-hard	38.24	7.8	5.9	1.9	Several months
Caerphilly .	Semi-hard	37.11		5.9		Few months
Derby .	Hard	35.61	8.0	6.0	2.0	Several months
Double Gloucester	Hard	35.77	8.2	6.1	2.1	Up to 1 year or longer
Dunlop .	Hard	34.45	8.2	6.1	2.1	Up to 1 year or longer
Cheddar .	Hard	34.08	8.2	6.1	2.1	Up to 1 year or longer
Gruyere .	Hard	31.25	8.6	5.9	2.7	Up to 1 year or longer
Parmesan	Very hard	19.97	9.5	7.0	2.5	Several years

SUGGESTED RHEOLOGICAL DEFINITION FOR CHEESE TYPES
(All measurements on mature cheese)

Type	*Moisture* (%)	*pV*	*pM*	*pS*
Very hard .	<25	>9	>6.3	>2.3
Hard . .	25–36	8–9	5.8–6.3	2.2–2.3
Semi-hard .	36–40	7.4–8	<5.8	1.8–2.2
Soft . .	>40	<7.4	<5.8	<1.8

Usually some two hours or longer are required before the curd is ready for milling or grinding, and it is interesting to watch the change in the curd during this period. It becomes drier, more mellow and silky and changes from a sorbo-rubber-like material to one intermediate in feel and appearance between chicken-breast meat and dough. Perhaps the most characteristic feature is the fact that in the later stages it can be torn into leaves rather like soft muscle and develops a characteristic nutty and buttery aroma.

(viii) ***Milling.*** The correct point for milling is difficult to determine and calls for considerable experience in the cheesemaker. It is usually considered that the acidity should be five times that of the evening milk, and if this is 0·17 the acidity at grinding should be 0·85. However, the curd is now so dry that it is difficult to obtain whey for the acidity measurement, and in any case when whey has to be squeezed from the curd the error is considerable. Most cheesemakers carry out a " hot iron test " on the curd during the later stages of cheddaring and especially to determine if the curd is ready for milling. The fact that the mellowed curd can be torn into leaves indicates that considerable changes in the protein have taken place, especially in relation to the orientation of the protein molecules which are now so arranged that the curd exhibits the property of anisotropy. If melted by heat the molten material exhibits a marked ductility, and this is the basis of the hot iron test. An iron bar, usually about an inch wide and a quarter of an inch thick, is heated to a " black heat " and a piece of curd, squeezed to remove adhering moisture, is rubbed against the hot iron and then slowly drawn away. The length of the " threads " that can be drawn is a measure of the acidity developed in the curd. Experienced cheesemakers usually place more reliance on this test than on any other for acidity at the milling stage. The curd is usually allowed to mature until threads of 1½ to 2 in. can be drawn. The test is obviously a composite one and measures not only the acidity but also the condition and degree of digestion of the curd. Coppen has described various tests on curd at milling. For Cheshire cheese the most useful is a special knife which cuts through the curd, the force required to make the cut being measured. So far the results for Cheddar are of less practical value than those for Cheshire.

Grinding consists in passing the curd through a mill which tears it into small pieces. The curd is then well stirred and salt added at the rate of about an oz. to 3 lb. of curd. Salt has a number of functions in cheesemaking. Not only does the brine formed dissolve some of the protein and so assist in the matting of the curd, but it also controls bacterial activity and the rate of ripening. Cheese made without salt are soft, ripen quickly, and rapidly develop unpleasant flavours.

After salting the curd is thoroughly mixed, allowed to stand for a short time, and then filled into cloth-lined hoops or moulds under hand pressure (Fig. Ch 6). When filled the cheese is put to press under gentle pressure which is steadily increased up to about 20 cwt. in 2 hr. (Fig. Ch 7). During the first three days, the cheese receives constant attention by turning, washing, greasing, and bandaging. At the end of this time it resembles the finished product in appearance but is still quite soft.

A good Cheddar cheese usually develops the characteristic flavour in about three months, and should be consumable at any time from three months up to a year or longer. A cheese store is illustrated in Fig. Ch 8.

Nutritive Value. Cheese is universally recognised as a first-class food. The nutritive value of cheese and other common foods is illustrated in Tables NV VII and NVF 1 (p. 1131). It will be noticed that from practically every point of view cheese is in a class by itself. The most important aspect of a foodstuff is its content of first-class protein, and bearing this fact in mind there can be little doubt that cheese has a considerable claim to be regarded as the " king of foods ". Not only is cheese of high calorific value and very rich in first-class protein and fat, but it is exceptionally rich in calcium and is also rich in phosphates and vitamins

CHEESE

Consumption (1930).

TABLE Ch V

Country	Per capita consumption	
	Lb. per annum	*Lb. per week*
Switzerland	23·3	0·45
France	13·5	0·26
Netherlands	12·3	0·24
Italy	11·8	0·23
Great Britain	9·5	0·18
New Zealand	5·8	0·11
U.S.A.	4·3	0·08
Australia	3·7	0·07
Canada	3·0	0·06

Trade Figures.

TABLE Ch VI

CHEESE—WORLD FIGURES (thousands of cwt.)

	Export			*Import*	
	1933	1938		1933	1938
New Zealand	1983	1610	U.K.	3016	2911
Netherlands	1258	1151	Germany	812	640
Canada	662	723	Belgium	432	475
Italy	469	476	France	412	280
Switzerland	402	442	U.S.A.	432	486
Australia	97	314	Italy	89	91
France	224	237	Algeria	96	89
Denmark	198	179	Egypt	55	67

TABLE Ch VII

IMPORTS INTO U.K. (thousands of cwt.)

	1913	1933	1936	1938
New Zealand	547	2059	1681	1639
Canada	1294	630	603	678
Australia	8	93	91	238
Netherlands	292	122	182	202
Italy	102	90	14	71

TABLE Ch VIII

OUTPUT OF CHEESE IN GREAT BRITAIN (cwt.)

Year	*Factory*	*Farm*	*Total*
1930	460,000	689,800	1,149,800
1934	726,000	276,000	1,002,000
1936	856,500	237,800	1,094,300
1938	600,900	266,700	867,600

TABLE Ch IX

RELATIVE PROPORTION (per cent.) OF VARIETIES, ENGLAND AND WALES, 1938

	Factory	*Farmhouse*
Cheshire .	35·3	55·3
Cheddar .	35·2	25·8
Lancashire	10·9	13·7
Stilton .	7·2	0·5
Caerphilly .	4·5	
Leicestershire	3·2	
Wensleydale	2·5	
Derbyshire .	1·1	
Others .	0·1	4·7

A and B_2. These outstanding characteristics of cheese make it of considerable value for children and adolescents.

Faults in Cheese (with special reference to Cheddar). Faults arise by deviation from the normal path of ripening due to the abnormal composition of the milk, the presence of foreign substances, the growth of abnormal bacteria or errors of judgment in the process of manufacture. It is convenient to consider cheese faults under the following headings: (*a*) Physical faults, or those of texture, body, etc. (*b*) Chemical faults, or those due to chemical action of the constituents of the cheese independently of the micro-organisms. (*c*) Bacterial faults, or those due to the products of growth of fault-producing bacteria. (*d*) Physiological faults, or those due to abnormalities in the milk itself.

(*a*) PHYSICAL FAULTS are faults in the make-up of the curd and are due, assuming that a normal milk has been used, to errors in the method of manufacture, such as insufficient acidity at renneting.

Dryness or *dry body* is usually caused by lack of moisture in the final product. The excessive loss of moisture may be due to a variety of reasons. Heating the curd at too high a temperature or for too long a period may result in a rubbery curd. Excessive stirring may produce the type of curd known as mealy or sandy. The factors controlling the loss of moisture from the curd while in the whey are size of cutting, temperature or warmth, acidity or the amount of lactic acid produced by the streptococci in the curd, and the time or period of treatment. If it is found that curds are produced with the above-mentioned faults, adjustment of the time and temperature of scalding must be made. In addition the thermometer should be checked.

A salty taste indicates that too much salt has been added to the curd. Excess salt has the effect of drying the curd and should be avoided. Dryness in general can be mitigated by paraffining the cheese and by ripening in a humid atmosphere. Another form of dryness is that due to a low proportion of fat in the curd. This may be caused by using milk from which part of the fat has been removed.

Loose or *open texture* is characterised by holes and frequently by soft body. It is usually due to working at insufficient acidity with the consequent retention of whey. Pressing the curd for too short a period and at too high an initial temperature will also accentuate this fault, which may be avoided by keeping the acidity well up, especially before renneting, and by cooling the curd before putting to press. Cheese liable to this fault should be well pressed and ripened at low temperatures.

Greasy textured cheese have an accumulation of fat in the holes and at the surface of the curd. The fault is most common in the spring and in dry weather because of the increase in the ratio of fat to casein in the milk. As the curd consists of fat, casein, and water, it is to be expected that excess fat in the curd will increase any tendency there may be for it to be expressed. Uneven distribution of the fat in the milk, such as that due to creaming, should especially be avoided. Milk from the Channel Islands breeds being richer in fat and containing larger fat globules is especially liable in this respect, as the larger the globule the more rapid is the rate of creaming. Working at too high a temperature, careless handling of the curd, piling too high, and rough milling all increase the tendency for the fat to be expressed. Should greasiness be experienced the most careful treatment should be given to the curd. Over-heating should be avoided and the curd piled low.

Paleness or lack of colour is usually due to over-acidity, which is generally caused by the use of too much starter. Should this fault be experienced, special attention should be given to the firming of the curd in the whey before pitching. It may be advisable to stand the curd for some time after salting. If annatto is used, paleness may be due to a poor quality of colouring matter.

Mottling in any form is due to non-uniformity of conditions in, or treatment of, the curd, such as acidity, moisture, cutting, piling, etc. Care should be taken to carry out all operations as uniformly as possible, especially the cutting, heating, and stirring. As the rate of clotting is frequently not uniform throughout starters, it is a definite advantage always to strain the starter. Once mottling has occurred it cannot be remedied.

A form of mottling has been described as due to the expression of white fatty whey from the curd, accompanied by a tendency for putrefaction on account of the accumulation of albumin in this liquid expressate.

Seams are caused by the uneven absorption of salt on account of the greasy nature of the curd. This fault may be confused with those of mottling and greasiness with which it is closely related. Some cheesemakers rinse the curd with warm water just before salting, but this practice may lead to other faults. Impurities in the salt are said to accentuate this fault ; hence it is important that only the purest kinds of salt should be used.

Cracked rinds or openings in the surface of the finished product are due to distortion at or near the surface. These internal stresses may be caused by excessive acidity (which has a powerful effect on the shrinkage of the curd) or to weakness in the coalescing properties of the curd due to lack of acidity or to insufficient pressing. Too dry a ripening atmosphere will accentuate this fault. Good coats are obtained by bathing in warm water during treatment in press, this process helping to preserve an even tension on the surface.

Sweating, or the exudation of liquid from ripening cheese, is a complicated phenomenon controlled by the structure of the curd, the amount of free liquid inside the cheese, and the internal pressure. Over-acid cheese frequently run. The powerful influence of acidity on the structure and shrinkage of the curd has already been mentioned.

Physical openness is a fault as yet but little understood. It is due apparently to some defect in the make-up of the proteins of the cheese. The pasteurisation of milk presents a special case of the problem and bad cases of this have been experienced. The cheese on cutting rises in a manner indicating very powerful distortion inside, large slits appearing and increasing in size as the cut cheese is allowed to stand.

(*b*) CHEMICAL FAULTS are those due to purely chemical action, *i.e.* independent of the micro-organisms in the cheese. They are usually due to the presence of foreign substances such as lead and iron in the cheese.

Black metallic discoloration is due to tiny particles of iron, lead, and similar metals derived from the steel wool used for cleaning the vat or from other sources. Iron is turned black by sulphuretted hydrogen, which forms iron sulphide. Albumin contains sulphur compounds which, under the reducing conditions present in the cheese, may be split up by some bacteria with the formation of this gas.

Copper and lead have similarly been shown to be capable of producing this fault. These metals also form black sulphides. Various shades of colour such as blue, grey, and brown may be caused by these metals according to different conditions obtaining in the interior of the cheese. Some types of annatto apparently contain red lead added to improve the colour, and this compound readily gives the black sulphide. These discolorations appear indiscriminately as small diffuse dark spots in the interior of the cheese. A nucleus of metal may sometimes be found microscopically.

Pink or red discoloration in cheese coloured with annatto and containing saltpetre, according to the practice of some cheesemakers, may be caused by a peculiar sequence of reactions described by Canadian workers. The first was the reduction of the nitrate, or saltpetre, to nitrite, a salt which under certain conditions may couple with some organic compounds to form a dye. Annatto is a naturally occurring dyestuff which can couple in this way to form a more highly-coloured compound. The reduction of the nitrate was brought about by certain types of bacteria isolated from the infected cheese, and it was shown that all the faulty cheese contained organisms capable of reducing nitrate to nitrite. The fault did not occur in cheese which did not contain these organisms, saltpetre, and annatto, *i.e.* all three components were necessary for the coloured compound to be formed. The coloured compound did not appear until some of the nitrate had been reduced to nitrite, thus making the second reaction or coupling possible. This is a striking example of the fact that cheese ripening, both in its normal and abnormal aspects, is an association of many reactions, most of which are interconnected and cannot be altered or suppressed without affecting others. The use of annatto in cheese renders the product liable to special faults, some of which are described elsewhere. It is most important to use only a pure annatto free from metallic contaminants, to mix it evenly with the milk and to vary the colour according to the requirements of the market.

(*c*) BACTERIAL FAULTS. By the time of pressing, the flora of the curd is practically a pure culture of streptococci, because although other bacteria are present—having been put into the milk fortuitously or with the rennet conditions so favour the former or true lactic acid bacteria that the latter miscellaneous types either die out or exist only in very small numbers. Should, for any reasons, the conditions be upset so that the so-called miscellaneous bacteria are able to flourish or compete successfully with the streptococci and lactobacilli, they may make their presence known to the casual observer by the production of odours, liquefaction, pigmentation, or gas. This abnormal growth will result in a faulty cheese.

Over-acidity is caused by the too rapid development of the starter organisms and hence must be considered as a bacterial fault. Acidity is possibly the most important single factor controlling the manufacture of Cheddar cheese, its importance depending upon the fact that it inhibits the growth of undesirable bacteria (the putrefactive bacteria flourish best in neutral or slightly alkaline media), activates the enzymes of the rennet and controls the rate of shrinkage and the coalescing properties of the curd. It is thus important to watch carefully the rate of development of acidity throughout the whole process of manufacture. Formerly cheesemakers relied upon empirical observations, having found by experience the effect of variations in the acidity upon the feel of the curd. The hot iron test was probably the first attempt to measure the development of acidity, and this test, crude as it may appear to the scientifically trained, is based upon fundamental physical and chemical laws, and is capable of giving fairly accurate information upon the acidity developed at various stages. The acidimeter or apparatus for performing titrations is now in universal use, and titration must be considered the first of a number of scientific methods adapted to the control of cheesemaking. This will in time probably be replaced by a simple method of estimating the acid intensity or real acidity, as it is this, and not the titratable acidity, which controls the behaviour of the curd. The reason why milks of high initial acidity require higher titratable acidities than do normal milks is because milks of high initial acidity have greater acid-absorbing capacities, or are more highly buffered. This is an example of a rule of great practical importance, discovered empirically by practical cheesemakers, which is readily explained by known physico-chemical laws. Excessive acidity will result in a mealy or sandy curd with a sour taste. It is important to correlate the firming of the curd in the whey with the rate of development of acidity, as this fault may be due, not to too high an acidity, but to insufficient firmness of the curd. The fault may also be caused by using milk which has ripened or developed too high an acidity (lactic acid acidity) and, even when a normal amount of starter is used, by having in the natural milk flora organisms which stimulate the production of lactic acid by the starter. Bacteria which render the casein soluble (peptonising bacteria) frequently have this effect on starter.

The problem of dealing with over-ripe milk or a vigorously growing starter in the milk and curd may be tackled in two ways, firstly, by so controlling the manufacture that the rate of development of acidity is kept down as much as possible, and, secondly, by accepting the state of things and accelerating the process of manufacture to fit in with the increased ripening. The acidity may be kept down by employing lower temperatures than usual, and at a later stage of manufacture by using an extra amount of salt which depresses the rate of growth of the lactic acid bacteria. Acceleration of the manufacture may be achieved by using extra rennet, cutting into finer pieces, heating the curd to higher temperatures, and running the whey down to the level of the curd as soon as possible after scalding.

Gassiness is caused by the fermentation of lactose in the curd with the production of gas, chiefly carbon dioxide and hydrogen. Of all the bacteria capable of producing gas in cheese, the *coli-aerogenes* are by far the most frequent. This group consists of the true coli originating from faecal sources and the aerogenes bacteria which are found chiefly in soil, water, and on plants, and rarely in dung. Both produce gas, the aerogenes in greater quantity, but the coli with more offensive odours. In addition the presence of coli is more suggestive of direct manurial contamination. The most common sources of both types in dairy practice are dirty utensils, but the infection may be introduced through the milk or starter, more frequently the former. It has been stated by a competent and experienced authority that of all the known tests for milk which is to be used for cheesemaking, the coli test gives more useful information than any other. The fault is more likely to be encountered in hot weather owing to the fact that the coli-aerogenes bacteria grow much faster at higher temperatures. The starter organisms can compete successfully with coliforms at 70° F. Hence a little starter added to the evening milk may be useful in very bad cases. It is also advisable to raise the acidity all through the manufacture, to press well and to keep the green cheese in as cool a place as possible, as the streptococci thrive at temperatures at which the coliforms grow with difficulty. Some cheesemakers add saltpetre to the curd at the time of salting to repress this fault. The saltpetre acts chemically as an oxidising agent, and so alters the chemical action of the coliforms that gas production is decreased or inhibited. *See* Coliforms. "Blowing" in cheese, especially in processed cheese, may be caused by the butyric acid bacteria. It is possible to prevent or minimise this trouble by adding a suitable antibiotic or antibiotic-producing starter (Mattick and Hirsch (1947), *Lancet*, **253**, 5; Blan (1950), *M*, **5**, 149; Kooy and Pette (1952), *NMDJ*, **6**, 302, 317). *See* Stability.

Liquefying cheese or "slippers" are fortunately rare. This phenomenon is due to proteolytic or "casein liquefying" organisms such as those of the *proteus* group "getting away" or growing with extreme rapidity in the cheese. This liquefaction is usually most evident near the surface and so causes the cloth to slip off when the cheese is handled. Only those organisms able to grow at the acid reactions found in cheese will cause this fault. Fortunately proteolytic organisms usually grow only at neutral or mildly alkaline reactions, and so the natural acidity of the cheese prevents their growth in all but exceptional cases. Acidity is thus the reason why it is possible to preserve fermented milks and other foodstuffs for longer times than would otherwise be possible. The products of growth of the acid-forming bacteria which constitute the flora of these fermented foodstuffs are harmless or even beneficial to the consumer, whereas the liquefying and putrefactive bacteria produce nitrogenous compounds which are highly toxic to animals. In all such acidified foodstuffs, yeasts and moulds sooner or later destroy the acidity by feeding on the organic acids, thus paving the way for the proteolytic or putrefactive organisms. This is the course of events when cheese or any other foodstuff is allowed to stand indefinitely. Once liquefaction has started in a cheese it is impossible to counteract it.

Sliminess is a fault similar to the preceding one. It is due to the growth of certain caseolytic organisms which convert the protein into ill-defined soluble decomposition products. Various moulds, particularly *Mucor*, and certain chromogenic bacteria have been described in the literature as causing this fault, while other cases due to putrefactive bacteria are alleged to have been caused by infection of the milk from compound feeding cakes. Sliminess is usually confined to the surface layers of the cheese. Mould growth in such cases may be inhibited or repressed by applying a solution of borax to the coat of the cheese, while chromogenic bacteria are best prevented from growing by swabbing with methylated spirits.

Openness or " holeyness " is generally due to the growth of yeasts in the interior of the cheese. Such holes are characteristic in appearance, glossy-coated and sometimes described as " fish-eyed ". Yeasty openness may be distinguished from physical openness by the fact that the holes do not change in shape or size on cutting, are glossy-coated and, of course, give yeasts on culture of the inner surface of the hole. *Torula cremoris* has been shown to cause this fault in New Zealand, and, in addition, to impart to the cheese a flavour of amyl alcohol. Heterofermentive lactobacilli can also cause holes in Cheddar cheese.

Bitterness in some cases has been shown to be caused by yeasts and, in others, by atypical lactic acid bacteria. Various species of liquefying bacteria have also been described as causing the fault. A very slight bitterness is part of the true Cheddar flavour and is probably due to certain peptones. Accentuation of the reactions causing their formation by the organisms described as responsible for the fault must be the cause of the abnormal bitterness. Faults of flavour such as this are the most delicate and least controllable of all, as extremely minute quantities of the substances responsible can affect the palate. For example, tributyrin is extremely bitter, and certain fat-splitting bacteria may cause bitterness by producing this substance.

Fruitiness is invariably ascribed to yeasts, but bacteria exist which can produce these characteristic flavours, and one case of fruitiness has been shown to be caused by a strain of *B. coli*. Pineapple, apricot, and strawberry flavours have been traced to the growth of *Torulæ* (a type of yeast) which gained access to the cheese from the whey tanks.

Stinking cheese are those affected by a serious and treacherous fault which may not become evident until the cheese are five months old or more. Thus a cheese which is apparently quite free from any fault or taint when two or three months old, may become quite unsaleable three months later. The fault is caused by the growth in the interior of the cheese of anaerobic sporing bacilli (or *Clostridium*) capable of forming sulphuretted hydrogen, mercaptans, and amines from the proteins of the cheese. These chemical substances have the most disagreeable odours of any known, are extremely offensive, and, once they have tainted a cheese, sale becomes impossible. The source and mode of entrance of these bacteria have not yet been proved, but the rennet appears to be a possible source, as organisms capable of producing odours resembling those in the faulty cheese have been isolated from commercial rennets. It has also been suggested that dried starter powders may be the source of these anaerobes. No definite proof, however, that either of these products is responsible, has been published.

Rancidity may be due to the production of butyric acid and related compounds by the butyric acid bacteria which probably form these substances from the lactose or fat. This fault is most common in the spring, and the sources of infection have been shown to be stale milk, manure, soils, road dust, and impure starters, the last quite frequently. The fault has been reproduced in cheese by adding to the milk materials known to be the source of these bacteria. Rancidity can also be caused by enzymic lipase in the milk ; thus the " kexey " taint familiar to Somerset graders can be reproduced by adding lipase to cheese milk.

Black spot is usually due to metallic contamination, but an organism, *B. lactis niger*, has been shown to be the cause of one kind of black spot in cheese.

Reddish discolorations occur in a number of forms. One is that of a pale pink-brown diffuse discoloration near the rind which only appears in ripe cheese. This is an oxidative process, as it increases on exposure to air and so resembles that responsible for the production of the melanin type of pigment. Moulds (*Oospora*) have been isolated from such discoloured cheese and shown to be capable of producing the same colour in media containing tyrosine. These moulds are not, however, visible in the cheese itself. Various organisms have been described as causing discolorations, but the bacteria identified do not appear to have been found by other workers.

Rusty spot or *red spot.* This fault has been shown to be caused by the growth in the interior of the cheese of an atypical lactic acid bacterium termed *L. rudensis.* It is really a pigmented variant of *L. pentoaceticus.* Investigations have shown that, although the whey on an infected farm is heavily seeded with the bacterium, it is already in the milk before it enters the dairy. Thus, although the chief contamination undoubtedly occurs from the whey and utensils, thorough sterilisation of all implements and the utmost cleanliness in working by experienced cheesemakers cannot eradicate the fault completely. The bacterium has been recovered from fore-milk samples and from milkers' hands, hence it is probable that it is part of the flora of the cow itself.

Milk drawn from cows suffering with mastitis is particularly potent in its ability to stimulate pigmented growth. The presence of surfaces (or interfaces) and beads of moisture is also favourable to the growth of *L. rudensis*, so that close-textured, dry cheese will be less likely to suffer from the fault than open-textured moisture-containing cheese. The fault may thus be minimised by producing the milk as reasonably clean as possible, by rejecting milk that is faulty in any way, and by making close-textured dry cheese. Acidities should not be low during the manufacturing process and whey should be led outside the dairy as soon as practicable. All utensils should be sterilised daily and the cheesemaker should wash his or her hands after touching articles outside the dairy which may be contaminated with the organism, *e.g.* old whey, foodstuffs, and wooden implements. Each cow should be tested separately for the presence of the organism and, if found positive, should be removed. *See* Stability.

Slow working of starters. See Starters.

(*d*) PHYSIOLOGICAL FAULTS. Slow working due to dysgenic milk is due to the secretion from one or more quarters of a cow (which may be apparently in good health) of dysgenic or " difficult growing " milk. Such milk has the property of inhibiting the growth of bacteria even when considerably diluted with other milk. All milk contains to some degree bactericidal substances, derived from the blood and the mammary gland, but usually they are present to such a slight extent that bacteria are able to multiply in the milk after a lag period of from 6 to 12 hours. A small quantity of dysgenic milk added to a bulk of normal milk may, however, inhibit the growth of starter to such an extent that cheesemaking is out of the question. The only remedy is to use each cow's milk in turn for starter propagation and so find by experiment which cow is producing dysgenic milk. The removal of this cow's milk from the bulk will allow ripening to proceed normally. The faulty milk may to all intents and purposes appear to be quite normal. The agents responsible for this strong inhibition of bacterial growth are probably globulin-like substances present in colloidal solution in the milk. The ordinary bactericidal substance in milk has been termed " lactenin " by American workers. Antibiotics such as penicillin used to cure mastitis may also produce " dysgenic milk ". *See* Antibiotics; Mastitis. The most common cause of " slow starter " is bacteriophage (p. 983). *See* also Starters.

Food flavours are the direct outcome of allowing the cows to feed on strong-flavoured food, especially just before milking. The most common causes of these food tastes are the strongly odoriferous feeds such as garlic, onions, leeks, turnips, rape, decayed silage, and certain weeds and green fodders. Such flavours in cheese may be distinguished from bacterial taints by the fact that they tend to decrease on standing, whereas the latter usually increase. Milk is an excellent absorbent of odours, due to the extremely large surface presented by the fat globules. If the milk has been exposed to objectionable odours, aeration may be required to remove the possibility of the cheese acquiring the taint. Doubtful feeds such as those mentioned above should be fed only after milking, as in cases due to these, the odours make their way into the milk via the blood stream. It is advisable to allow the curd to be thoroughly aired and to ripen the cheese at a low temperature.

Summary of faults. The four types of faults described may be avoided, speaking briefly, in the following ways:

Physical faults by strict attention to the method of manufacture, especially with regard to the acidity at various stages.

Chemical faults by scrupulous cleanliness in the vat and with the utensils, and by buying only the best starter, rennet, salt, and annatto (if this is used).

Bacterial faults by careful supervision of the method of production of the milk and its transport and storage in the dairy. It is not recommended that the cleanest possible milk be employed for cheesemaking, because we do not yet know enough about the role in the ripening played by the so-called " miscellaneous " bacteria, and it is possible that true Cheddar cheese cannot be made from very clean milk. Nevertheless, if milk containing a rich flora is continually used the possibilities of bacterial faults must be constantly borne in mind. A compromise may be reached by taking such precautions that contaminations by known fault-producing types will be prevented. The most frequent sources of such bacteria are dung, soil, fruit, and vegetables, especially if soured or fermented, feeding materials especially cakes, and stored whey. Should a bacterial fault be constantly experienced on a cheesemaking farm, it is an indication that the milk is being seeded with the causative organism at some stage. The only satisfactory method of eradication is to find the means whereby the organism enters the milk, and then to take steps to prevent it gaining access. This is often a difficult procedure, but much help is sometimes obtained by attempting to correlate the appearance or non-appearance of the fault with such incidents as cows going into new pasture, atmospheric dryness and consequently dustiness, the use of different starter, rennet, or salt, the omission of the milk of certain cows from the cheese bulk, and lastly, the keeping of old whey in the dairy.

Physiological faults by regular examination of the cows by a competent person or veterinary surgeon. Milk from any quarter which is at all doubtful in appearance should be excluded from the cheese vat. The bromcresol purple paper test is invaluable for this purpose, as at negligible cost and time the milk from each quarter of individual cows may be tested. This test is not reliable in the sense that it will always indicate whether a milk is abnormal or not, but a positive reaction (or purple coloration) may be taken as a certain indication that abnormal milk is being secreted, probably due to an inflammatory condition of the udder.

Description of Cheese Varieties. In this section methods in use in 1939 are given. During the war and since, methods have in some cases been altered to give a longer-keeping cheese, and annatto was excluded. Some varieties are now not being made. It should be clearly understood that methods vary from place to place and may alter from time to time. Acidities given in manufacturing methods refer to the technique using 3 drops of 0·5 per cent. phenolphthalein solution to 10 ml. milk or whey.

Varieties of Cheese. APPETITOST (appetiser). A crude type of cheese made from sour butter-milk in Denmark and to some extent in neighbouring countries.

BACKSTEIN. A limburger type made in the shape of a brick.

BELLALAY. A soft cheese made in the Bern canton in Switzerland. An alternative name is Tête de moine or Monk's head.

BEL PAESE CHEESE. A soft, very white cheese of relatively recent origin, the name being the copyright of the Italian maker who originated it. It resembles a partially ripened Brie. Similar cheese are marketed under the trade names of Fleur des Alpes and Schoenland. Its manufacture has been worked out in America and is described below. It has a characteristic mild, slightly salt, lactic flavour, and a soft, waxy texture. A small quantity of starter is added to good-quality raw or pasteurised milk and enough rennet added to the milk at 104° to 110° F. to give a suitable curd in 15 min. It is then cut, stored, the whey run off, and the curd dipped into suitable forms. Draining requires from 5 to 7 hr. at 80° F., the cheese being occasionally turned. Salting is carried out by immersion in 16 to 18 per cent. brine at 54° to 60° F. for 14 to 18 hr. The salted cheese are ripened at a temperature of 40° to 45° F. and a humidity 80 to 90 per cent. After about 20 days the cheese is wrapped in tinfoil or other material and ripened for a further 2 to 4 weeks. The cheese should be consumed within 2 months of ripening. From 11 to 14 lb. cheese are obtained from 100 lb. of milk.

BLEU. A general name applied to varieties made in France in imitation of Roquefort. An alternative name is Fromage persillé.

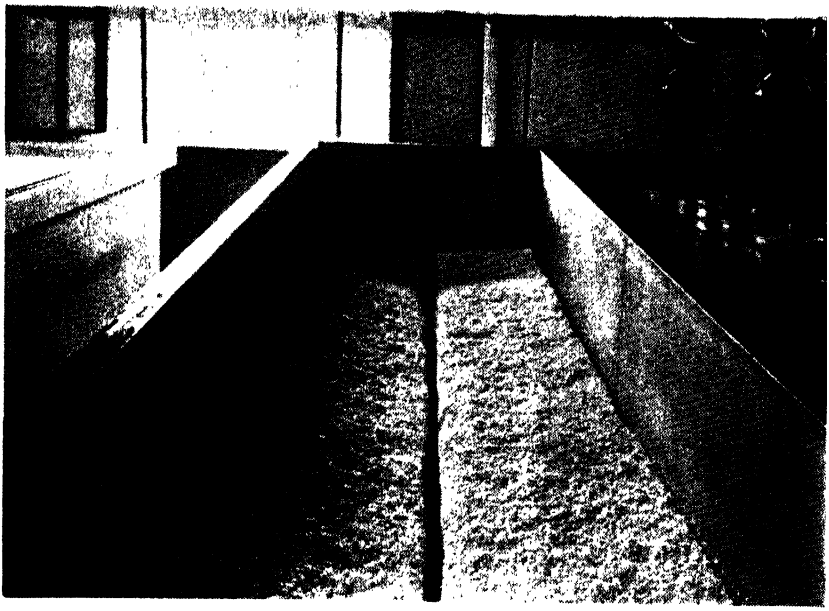
BLUE VINNEY. *See* Dorset blue.

BONDON. A popular variety of French soft cheese.

BRICK CHEESE. An American variety, intermediate to Limburg and Emmenthal or Gruyère. It is made from cow's whole milk and the derivation of the name is supposed to be from the fact that bricks are used for weighting down the cheese in the press. It has a springy body in which are found many small round holes and the taste is strong and sweetish. It is rectangular in shape and measures 10 × 6 × 3 in.

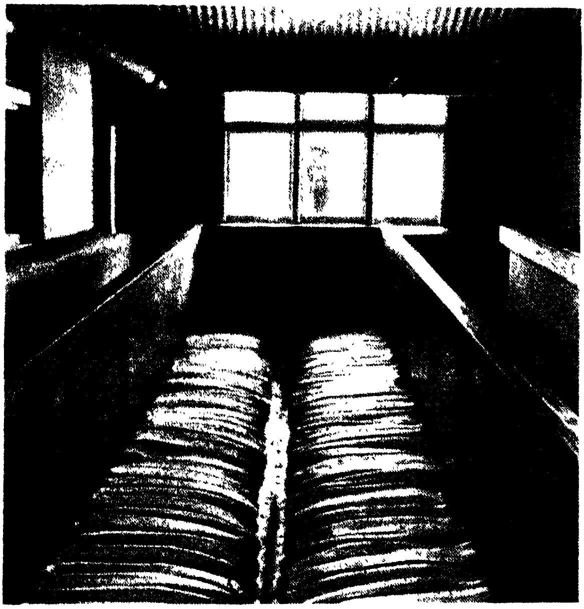
Sufficient rennet is added to sweet milk at 86° F. to coagulate it in about 25 min. After cutting, the curd is heated to about 115° F. and scalding continues until the curd is of the required firmness. It is then packed into the hoops, which are rectangular boxes without bottoms and with slits at the sides to allow drainage. The hoop is then set on the draining-table and one or two bricks placed on the curd to assist drainage. After a day these are removed and the cheese rubbed with salt and piled three high. Salting is carried out three times in all and the cheese are then taken to the ripening cellar, which should be ist and at a temperature of 60° to 65° F. The cheese ripen in about 2 months.

BRIE CHEESE. This variety closely resembles Camembert and is a soft cheese made from cow's milk, which may be whole or partly skimmed. Brie has been known in France for several centuries and is imitated in many countries. To make Brie cheese, milk should be perfectly fresh, but evening's milk, if kept cool over-night, may be used with the morning's milk. The milk is renneted at a temperature of about 82° F. and a little artificial colouring matter may be added before renneting. After standing for about 2 hr. the curd is put into hoops,



[By courtesy of United Dairies Ltd.

FIG. Ch 4.—*Curd in Vat after Removal of Whey.*

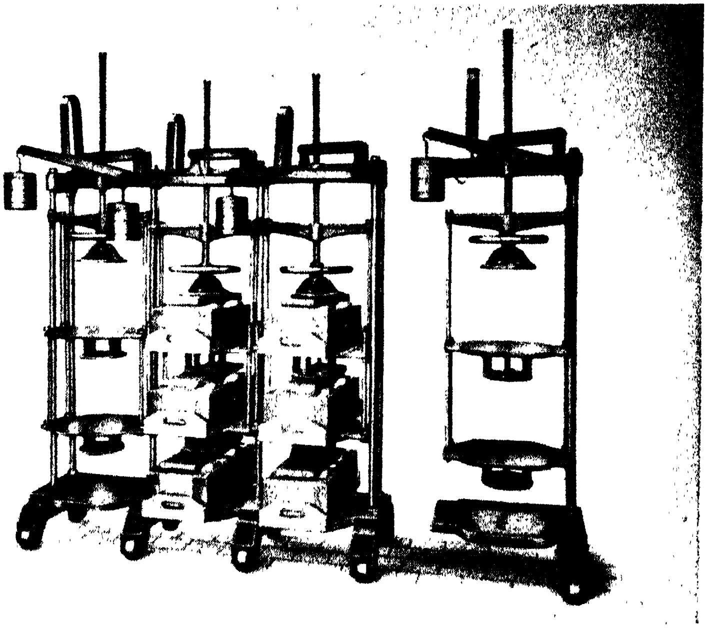


[By courtesy of United Dairies Ltd.

FIG. Ch 5.—*The Curd cut into Blocks.*

[*By courtesy of United Dairies Ltd.*

FIG. Ch 6.—*Filling the Milled Curd into Hoops or Moulds.*



[*By courtesy of Hiron & Rempler Ltd.*

FIG. Ch 7.—*Cheese Presses.*

which vary from 6 to 15 in. in diameter and from 2 to 3 in. in height. The cheese are allowed to drain for 24 hr. without pressure and then the hoops are removed and salt is sprinkled on the surface of the cheese. The first ripening period should take place in a dry, well-ventilated room. After about 8 days, when moulds begin to grow on the cheese, it is transferred to a cellar, which should be dark, not too well ventilated, and at a temperature of about 55° F. Brie ripens in from 2 to 4 weeks and a characteristic red colour appears on its surface, due to the growth of a pigment-forming bacterium. The ripening is brought about largely by the moulds which grow on the surface of the cheese and whose enzymes diffuse into the interior. When fully ripened the cheese mass may vary from a waxy to a semi-liquid condition and has a characteristic sharp taste and powerful ammoniacal aroma.

BRINSEN CHEESE. This variety, which is also known as Liptau, is made from sheep's milk or the mixed milk of sheep and goats in the Carpathian mountains of Hungary. From 2 to 4 gal. of fresh milk are heated in a kettle and renneted at a temperature of about 80° F. Coagulation takes place in 15 min. and then the curd is broken, the whey dipped off and the curd allowed to drain in a sack for 24 hr. After cutting into pieces it is placed on a board where it remains until it begins to get smeary. This requires about 8 days. The pieces of curd are then piled in a vessel for 24 hr., after which they are removed, the rind cut away and the partially ripened cheese broken up in another vessel. Salt is then rubbed in and the curd finely milled and packed into a tub with beech shavings.

CACCIOCAVALLO CHEESE. This cheese was originally made in the south of Italy but is now made all over that country. It has been known for centuries. The name means literally " horse cheese " and various explanations of the significance of this name have been offered. One suggestion is that it was originally made in the neighbourhood of Monte Cavallo and another that the original trademark was a horse's head.

Cacciocavallo is made from cow's milk either whole or partly skimmed. The milk is renneted at about 92° F. and after half an hour cut very fine and sometimes allowed to ferment for a day. It is then heated by hot water or whey, and hand worked until the curd becomes homogeneous and can be drawn out into long threads. It is next moulded, soaked in brine for 2 days, and suspended from the ceiling and lightly smoked, the surface afterwards being rubbed with olive-oil or butter. The cheese weigh about 3 lb. and vary considerably in shape, the most common being that of a beetroot. They may be eaten fairly fresh or after some months' ripening, when they are grated and used for flavouring soups.

CAERPHILLY. Although sometimes called a hard variety, Caerphilly is really a lightly-pressed cheese. It has a springy body, a mild flavour, and is not coloured. It is made for a special market, the mining communities of Wales, and the south-west of England. Originally a Welsh cheese, it is now made in all parts of England and has special advantages for the small cheesemaker. Thus it can be made with small quantities of milk, and the high yield (about 1¼ lb. cheese per gal. of milk) should result in a good profit for the farmer. It ripens quickly and is soon marketed, so that little storage space is required and a quick return obtained. It is a comparatively simple cheese to make and can be made all the year round, If, for any reason, making Cheddar is unprofitable or attended by risk, Caerphilly represents a suitable outlet for the milk. The most popular kind is a quick-ripening variety which can be consumed 14 days after manufacture. It deteriorates rapidly after 4 weeks, however, on account of the high moisture content of the cheese.

Mixed evening's and morning's milk is used and the milk should be only slightly cooled. It is desirable for the evening's milk to have a temperature of about 70° F. in the morning, which allows a certain amount of ripening to take place. When starter is used the milk should be cooled to about 70° F. Sufficient starter should be added to produce an acidity of about 0·22 per cent. in nearly 2 hours. The morning milk is now added and the temperature raised to about 90° F. When the desired acidity has been reached, 1 dram of rennet is added for every 3 to 4 gal. of milk, and this should produce a curd ready for cutting in 40 min. The curd is cut into pieces about ¼ in. in size, gently stirred by hand for about half an hour, and the temperature gradually raised to about 92° F. After pitching, the curd is formed into a solid mass and the whey run off. The curd is next piled in a peculiar formation with the sides sloping into the middle. When an acidity of about 0·20 per cent. has been reached, the curd is cut into small pieces and again piled. At this stage it should be velvety in appearance. It is later cut into 1 in. cubes and salt added at the rate of 1 oz. for every 7 gal. of milk. The curd is next weighed out into moulds and pressed until whey exudes. The next day the cheese are taken from the moulds and soaked in brine for 24 hr. After removal from the brine they are dried and allowed to drain for 24 hr. before removal to the ripening room, which should be cool and airy and possess a temperature of 60° to 65° F. The cheese should be allowed to dry without direct draught. Before marketing, an imitation mould effect may be obtained by rubbing on flour or barley meal. This should not be necessary, however, as if the cheese have been made properly and ripened correctly, mould readily grows on the coat.

CAMBRIDGE OR YORK CHEESE. Our most important national soft cheese, and made principally in and around the Isle of Ely. It is made only in the summer months, as there is no demand for it except in hot weather. Being unsalted it deteriorates rapidly, so that its manufacture should run parallel with the demand. About 3 quarts of milk are required to make one cheese, and ¼ dram of rennet should be added for every 3 quarts of milk at a temperature of about 94° F. The cream is allowed to rise, *i.e.* the top of the milk is not stirred. When a firm junket has formed it is removed with a skimming-dish and placed in the mould or hoop in thin slices. The moulds are oblong and consist of a bottom portion which is pierced with draining holes. They are usually made of elm-wood about 7½ in. × 5 in. and 6 in. high. Wood is superior to metal on account of the greater conductivity of heat of the latter, and the curd adheres to the sides of the wooden mould, which results in the cheese settling first in the middle and so produces a characteristic curd which makes the cheese attractive. These cheese are not turned and may be sold when the moulds can be taken away without the cheese losing shape, usually about 2 days after making. The cheese weigh over 1 lb. and are consumed fresh. They are usually marketed in wooden boxes containing several trays, each tray bearing a single layer of cheese. Too high a temperature or too quick drainage will give a tough cheese; too low a renneting temperature or too rapid cooling of the curd results in a spongy cheese.

CAMEMBERT CHEESE. One of the most famous of the soft varieties, this is made in France from cow's whole milk, sometimes with the addition of a little skimmed milk. Camembert cheese are about 1¼ in. thick and 4½ in. wide, weigh about 12 oz. and twelve cheese may be obtained from about 5½ gal. of milk. It is found that difficulties occur in manufacture in hot weather and for this reason it is usual to make Camembert from September to May.

The milk is taken direct from the cow into wooden tubs which are fitted with lids and hold about 6 gal. each. The best cheese are obtained by the two curd system in which half the curd is filled into hoops in the evening and the remainder the following morning. One-half millilitre of rennet is used for every gallon of milk at a temperature of about 81° F.; coagulation occurs in about 2 hr. and the milk should be stirred occasionally to prevent the cream rising. As the mould peculiar to Camembert may not be present in English dairies, it should be inoculated into the milk before renneting. A culture can easily be prepared from a portion of good Camembert cheese. The curd is ladled into hoops of metal resting on straw mats on an inclined draining-board, and the cheese are then left over-night and in the morning will have drained to about two-thirds of their initial dimensions. In the morning the whole process is repeated, but before the new curd is ladled out, the surface of the old curd in the hoops is carefully broken up. This permits a sound joining of the two curds, and if this is not done the cheese is liable to break in half. Finally, it is important when ladling out the last portions that they should be placed upon the cheese in an unbroken position. The cheese then drain at a temperature of over 65° F., and a day after the second curd has been added the cheese should be more than half-way down the hoop and sufficiently firm to be turned. This operation requires much skill. The cheesemaker puts his left hand under the cheese, inverts the whole and steadies the cheese with his right hand, placing it inverted on a straw mat. If the drainage has proceeded too slowly the cheese will ferment, go spongy, and also tend to become slimy on the outside. This sliminess will prevent the proper development of the mould, and so these cheese are invariably inferior. When the curd has shrunk away from the sides of the hoop, the cheese are salted. The older cheese are first salted with evenly spread fine salt, about ½ oz. being required for each cheese. About six hours later the newer portions are similarly salted. The cheese can now be placed on shelves and must be turned twice daily. When the development of a fine white mould is evident, they are removed from the making room to the drying room. This room should possess means of controlling temperature and ventilation; the temperature should be about 55 F. and the air slightly damp. Under favourable conditions the typical Camembert mould grows rapidly and very soon the edge of the white mould turns blue so that the cheese presents a bluish-grey appearance. The cheese must now be removed from the cellar or cave. If the correct conditions are not obtained during this period in the drying room, faulty ripening will result. Thus, if the air is too dry the cheese may get greasy, and other moulds, dark green or black in colour, get a foothold. When the cheese are taken to the cellar they should be both soft and springy to the touch. Not much ventilation is required in the cellar and the humidity should be fairly high. The best temperature is about 50° F.; this greatly reduces the growth of the moulds which turn a reddish-brown colour. The cheese now become sticky and are considered ripe. They should be sold quickly for they possess those flavours which are characteristic of the type and deteriorate rapidly. The cheese are transported either in the familiar light wooden boxes or may be sent packed in straw six at a time. The correct ripening of a Camembert cheese is controlled by the sequence of the appearances of the moulds on the surface. If this differs from that mentioned, the cheese will not be first-rate. As described above, this sequence is white, changing to bluish grey and ultimately to reddish-brown. The cheese when cut through should be uniformly soft; a hard centre surrounded by a semi-liquid mass near the rind indicates a badly made cheese.

CHEDDAR. *See* page 171.

CHESHIRE CHEESE. Next to Cheddar, Cheshire cheese is the most popular hard-pressed cheese in England. It possesses well-defined characteristics and is especially in demand in the north of England. It may be described as crumbly or flaky in texture and mild in flavour. Both coloured and uncoloured cheese are made. This is, however, only a minor characteristic, depending on the particular market that the maker supplies. Generally speaking, the cheese made in the eastern part of the county and supplying the Manchester market is not coloured. The cheese is made in three varieties—early ripening, medium ripening, and slow ripening—but there is a tendency to standardise the product and to procure a uniform quality.

As with Cheddar cheese, Cheshire is made from mixed evening's and morning's milk. Temperature conditions should be so arranged that the milk is between 60° and 65° F. on the following morning. The cream may be skimmed off the evening's milk, raised to a temperature of 70° F., and the starter mixed into the cream and then passed back into the vat through a strainer, the purpose of which is to retain any clotted lumps which may have formed. The cream and starter are then thoroughly stirred in. Less starter is required with Cheshire cheese than with Cheddar, about 0·5 per cent. being used (1 pint to 25 gal. of milk). This should be sufficient to produce the correct acidity for renneting in from 1½ to 2 hr., and allow the completion of the making process in 4½ hr. Although in both Cheddar and Cheshire cheese the acidity at renneting is of prime importance, it is especially advisable when making Cheshire not to use too much starter, for the flavour and texture are adversely influenced by any excess. When the starter is well distributed in milk, the latter is gradually raised to the renneting temperature (86° F.). The morning's milk is then added and the whole bulk stirred occasionally to maintain an even temperature and to keep the fat uniformly distributed. If annatto is to be added, about 1 dram to 6 to 8 gal. of milk should be incorporated in the bulk after the addition of the morning's milk; the amount is varied according to the particular market for which the cheese is destined. In any case spring-made cheese may have a little annatto (1 dram to 50 gal. milk) incorporated in them. The rennet should be added at about 0·22 per cent. acidity, but it is usual to rennet at a slightly higher acidity in the autumn. The amount of rennet varies according to the time of the year, about 1 oz. to 16 gal. of milk being used in the early spring and 1 oz. to 20 gal. in the summer. Sufficient rennet should be added to make a junket firm enough for cutting in from 40 to 45 min. After dilution the rennet is added to the milk, the whole stirred for 3 min. and then the surface of the milk stirred gently until coagulation takes place—about 11 min. after renneting. The curd is cut lengthways and sideways with a vertical knife, left for 10 min. and then similarly treated with a horizontal knife. The cutting is continued until the pieces of curd are about the size of haricot beans. The acidity at this point should be about 0·14 per cent. Stirring by hand is now performed for about five minutes.

Scalding is carried out by raising the temperature slowly to a maximum of from 90° to 92° F. at a rate of about 1° per 4 min. As with acidities and other variable factors, the scalding temperature should be adjusted to meet the conditions of the moment. In some localities it may be necessary to use a slightly lower temperature in order to avoid too hard a curd, as, if the curd is allowed to harden a close-textured cheese will result. When the correct temperature has been attained, stirring is continued for about forty-five min. or until the curd is ready for pitching. The experienced cheesemaker is able to detect this condition by the behaviour of the pieces of curd in the whey. As moisture is expressed from the curd the specific gravity of the curd rises and so the particles sink more readily. The acidity at this stage should be 0·16 per cent. The curd is allowed to settle at the bottom of the vat and remain there until an acidity of 0·19 to 0·20 per cent. has been reached, which usually requires from 30 to 40 min. A useful indication is given by the shrinkage of the curd from the sides of the vat to a distance of from 1 to 1½ in. For whey-drawing the curd mass is cut into four pieces, the two nearest the tap placed on the two at the other end of the vat, and the whey then run off. Draining may take place either at the bottom of the vat or on a rack. The lumps of curd are broken and turned about six times in 1½ hr., and then left until 0·3 per cent. of acid is present in the whey. The pieces of curd are next broken with the hands, turning and breaking taking place every 20 min. The acidity should increase by 0·1 per cent. every 20 min. When ready for milling the curd should be firm, dry, and distinctly acid, showing a titratable acidity of 0·65 to 0·75 per cent., or giving a hot iron test of from 1 to 1½ in. After milling, the curd should be salted at the rate of 1 oz. to every 3 lb.; it can then be placed in the moulds and should have a temperature of about 77° F. It is desirable that the cheese should be kept at 70° F. in an "oven" if necessary. Draughts or a fall in temperature may result in a checking of the drainage. In the evening the cheese is put into a dry cloth and kept at the same temperature overnight. The next day, the cheese is put once more into a dry cloth and put to press, the pressure being gradually increased from 5 to 10, and in the evening to 15 and later 20 cwt. Pressing continues for about two days or until the cheese is dry. During the last period of pressing, a thin cotton cloth is put on the cheese in order to produce a smooth surface and sharp edges. When dry the cheese is capped at each end with a square piece of calico pasted on, bandaged with the same material and left in the press-room until dry. It is maintained at a temperature of about 60° F. and turned each day for a month, when it is ready for marketing. Cheshire cheese should keep for four months without deterioration.

Colwick. An English soft cheese, also known as Slipcote.

Coulommier Cheese. Best made in warm weather, as otherwise the dairy must be heated. One gallon of milk is required to make one cheese, which has the form of a flat cylinder about 2 in. high and weighing just over 1 lb. About half a dram of rennet is required for each 2 gal. of milk, which should be at about 84° F. and is stirred occasionally to keep down the cream. Three hours later the curd is ladled into circular tin hoops, which are made in two pieces, about 5½ in. across and 5 in. high, and held on draining-boards of yellow pine. The ladle is merely a tinned iron spoon about 4 in. across the bowl and fitted with a long handle. At the end of 3 or 4 hr. the curd should have shrunk into the lower half of the hoop, of which the upper part can be removed. When they retain their shape on removal from the hoop the cheese are salted, first by rubbing a little on the upper surface and then all over. Each cheese requires about 1 oz. of salt. The cheese are ready for despatch in from 2 to 3 days and are sent out wrapped in grease-proof paper. They are sold in an unripened condition.

Cream Cheese. In England cream cheese are mostly made in the summer months. Owing to the absence of any one particular method of manufacture there is no uniformity in quality of flavour, and in many cases the flavour is poor because of the impression that any sort of cream is good enough to make cheese. This is a fallacy, and it has been found that the flavour is at fault in 90 per cent. of exhibits, due very largely to too long a period of drainage. If cheese are properly made with the best cream, few branches of dairying are more profitable.

Two varieties are known : *double cream* (p. 190) made from cream containing about 50 per cent. fat, and *single cream* (p. 200) made from thin cream thickened with rennet before drainage takes place. If a certain amount of ripening is desired a small quantity of starter is strained into a gallon of cream.

Derbyshire or Derby Cheese. One of the oldest of our national cheese, but it was not until recently that a uniform method came to be adopted for its manufacture. Previously each farmhouse used its own method, and those farmers who were able to make better cheese than their neighbours kept the method a family secret. Under such conditions some first-class cheese were produced, but there were also many failures, chiefly due to lack of acidity and the production of " off-flavours ". This cheese is about 4½ in. high and 16 in. in diameter and weighs from 28 to 32 lb. ; 30 gal. are required to make one cheese and it is customary to use mixed evening's and morning's milk. About 0·4 per cent. starter is added and the milk renneted at 84° F. at an acidity of 0·19 per cent. about 1 oz. of rennet being required for 30 gallons of milk. If annatto is added, 1 oz. to 30 gal. of milk should be used. The curd is generally ready for cutting in from 40 to 50 min., and is scalded at 94° to 96° F., at which temperature it can be held for from 40 to 50 min. It is then pitched, the whey removed, and the curd transferred by a scoop into a cloth on a rack. After about fifteen minutes the matted curd is cut into about 9 in. blocks. The curd still retains a fair amount of moisture at milling, and the condition of the curd at this stage is of extreme importance. If it is too acid, a hard dry cheese possessing a disagreeable flavour will be obtained. Low acidities lead to a sweet cheese, leaking of whey during the ripening process and a tendency to develop " off " flavours. After milling, 1 oz. of salt to 3½ lb. of curd is added. Pressing takes place rather gradually at first, and is slowly increased until it may reach 20 cwt. on the second day. The cheese should be ripened at 55° F. for about three months, and during this time it must be turned daily. It is advisable to place the cheese in a cellar for the last 2 weeks of the ripening period, as the humidity and lower temperature give the cheese a good " bloom ".

DORSET BLUE CHEESE. Dorset Blue cheese (also known as Blue Vinney) is only made and sold to any extent in Dorsetshire. It is a skimmed-milk cheese and therefore permits the making of butter as well. As in other cheesemaking districts, owing to the certain market for liquid milk and the improvement in transport, many makers have given up making Blue Vinney, so that one has to pay a high price for a first-rate cheese. The weight of a Dorset Blue is usually from 14 to 18 lb. and it measures about 5 × 12 in. It possesses a comparatively hard body, a crumbly texture and a brown rough coat. It is rather difficult to attain uniformity in making this cheese.

Blue Vinney is usually made from hand-skimmed milk, and so the milk contains about 1 per cent. fat. Mechanical separation, which removes practically all the fat in the milk, would result in a hard dry cheese. It is usual to skim the morning's milk after 12 hours' standing, and again the next morning. The evening's milk is skimmed in the morning and mixed with the previous morning's milk. The mixed milk is then raised to about 75° F. and, when 0·35 per cent. of acid has developed, 1 dram of rennet added for each 6 gal. of milk. The curd is cut from 60 to 80 min. after renneting, gently stirred by hand for a few minutes, and then allowed to pitch until about 0·32 per cent. of acid is present in the whey. This usually takes about one and a half hours. When the whey has been run off, the curd is piled up on the two sides of the vat, covered with a cloth, and after 10 minutes' draining cut into blocks which are turned and piled in the vat. The blocks are then turned regularly at intervals of about half an hour. Milling is done when about 0·9 per cent. of acidity is reached, either mechanically or by hand. The milled curd is salted at the rate of 1 oz. for every 2½ gal. of milk. Special hoops are used for Dorset Blue cheese, and these are filled as usual with the small pieces nearest the rind of the cheese. The cheese is next pressed lightly for 4 hr., after which it is rubbed with salt, put in a fresh cloth, and pressed more heavily. The cheese should be ripened in a room that is slightly damp, free from draughts, and at a temperature of about 55° F. The coat begins to form in 2 or 3 weeks and the cheese should then be scraped at intervals. The time taken for the blue veining to appear varies considerably, about eight weeks being required under favourable conditions and 6 months when the curd is not so favourably structured.

DOUBLE-CREAM CHEESE. The thick cream is cooled in cold running water to below 60° but not below 50° F., and held at this temperature for 12 hr. The cream is then drained through fine linen, spread over a wooden form and is weighted if necessary to press out superfluous moisture. If it has been properly treated only skimmed milk should be pressed out. Drainage should be gentle at first, as otherwise the cloth will become clogged. This should be opened out once or twice in the first hour and scraped down, and then the 7 lb. weight replaced by one of 14 lb. The cream should be ready for moulding in 3 or 4 hr., and at this stage each pint of cream should have yielded 1 lb. of curd. Small metal moulds holding ¼ or ½ lb. and lined with parchment are now filled with the cheese by means of a wooden knife. When the mould is removed the cheese is wrapped round with muslin or paper.

If sweet cream has been used the cheese must be sold immediately, as off-flavours will appear in 2 or 3 days. It is advisable, therefore, if the cheese cannot be sold at once, to use slightly soured cream. If it is desired to salt the cheese, 1 oz. may be added to each gallon of cream.

Dunlop Cheese. This cheese takes its name from the town of Dunlop in North Ayrshire, where it has been made for at least 250 years. The manufacture is mainly confined to small farms in south-west Scotland. It is sometimes made in preference to Cheddar in the early part of the season and the total output is about 3000 tons per year. There is some demand for Dunlop from the south of England at certain times of the year, but this is largely governed by the availability of white Cheddar.

Dunlop has a higher moisture content than Cheddar. It is therefore more liable to bacterial faults. Clean milk is thus essential for making Dunlop cheese if a fine flavour and good keeping quality are to be obtained. First thing in the morning 0·25 to 0·5 per cent. of starter is added to the previous afternoon's milk and the temperature raised to 80° F. The morning's milk is then added and the temperature adjusted to 84° F. When the correct acidity has been obtained, 1 oz. of rennet is added to every 20 gal. of milk. The junket should be ready for cutting in 45 min., and at this point should split cleanly over the finger and come away from the wall of the vat cleanly. Cutting is carried out as for the Cheddar process and the acidity, after cutting, should be not more than 0·13 per cent. The temperature should now be adjusted to compensate for the loss of heat and the curd stirred gently by hand for 15 min. Scalding is carried out by raising the temperature 1° every 4 min. up to a maximum of about 97° F., which should be reached in about forty-five minutes. The curd may be stirred by a rake until firm enough to pitch. A common fault in making Dunlop is the failure to obtain sufficient firmness in the curd at this stage. When an acidity of 0·21 per cent. has been reached (usually about forty minutes after pitching) the whey is drawn. Two alternatives are now possible: (1) the curd may be shovelled out on to racks in the cooler and treated as in the Cheddar process, or (2) it may be allowed to drain in the vat. The second method is preferable. A drainage channel should be made by taking out a central strip of curd and spreading this on either side and the curd then covered with a clean warm cloth. When it has become a solid mass it is cut into 8 in. blocks, left for 15 min., and then cut into 4 in. pieces and tied into bundles and pressed with about 56 lb. In 30 min. the curd is torn up, rebundled, and again weighted. This treatment is continued until the curd is ready for milling. Rack drainage may be employed when a long-keeping cheese is required. The curd should be milled when an acidity of nearly 0·60 per cent. has been reached and then stirred by hand and cooled to about 80° F. Thirty minutes later salt may be added at the rate of 1 lb. to 56 lb. curd; the acidity should now be nearly 0·70 per cent. Fifteen minutes later the curd can be packed into the hoops (in Scotland termed "chessits"). The cheese are pressed lightly at first and then after about four hours put into a clean cloth, reversed in the hoop and left under full pressure over-night. The second day they are momentarily bathed in warm water and again pressed. Pressing continues for 3 days, at the end of which the cheese are greased, capped, and then pressed another day. The cheese are now bandaged with a winding bandage 3 in. wide and about 11 yd. long. Ripening requires at least 10 weeks, and the cheese must be turned twice daily for the first month. A common fault is fracture of the rind due to careless handling.

Dutch Cheese. *See* Edam and Gouda.

Edam Cheese. This is the better known of the two Dutch varieties of hard-pressed cheese imported into this country. It is made both on farms and in factories. The factory-made product utilises partly skimmed milk, while the farm product is a full-cream cheese and is seldom exported. The real Edam has at least 40 per cent. fat in the dry matter and the skimmed milk cheese at least 20 per cent. The exported cheese should bear a Government stamp stating the fat content. The cheese is spherical with flat top and bottom, and coloured red, but it may be packed in tinfoil, bladders, or tins when sent to hot countries.

To make Edam cheese, fresh milk is adjusted to about 83° F., colouring matter is added and sufficient rennet added to clot the milk so that it can be cut in 30 min. Twenty minutes later some of the whey is removed and the curd cut finer. More whey is then removed and the curd stirred, the temperature being raised to 92° F. After pitching, the layer of curd is cut into pieces about the size of a cheese. These are put into hoops and turned a few times, then wrapped in cloth and pressed for 3 hr. They may be salted either by rubbing in salt or by immersion in brine for 3 days. The flattening on the top and bottom is due to the regular turning of the cheese. The cheese are finally immersed in melted paraffin wax containing a red dye.

EMMENTHAL CHEESE. The classical Swiss hard-pressed cheese, this has the same standing in Switzerland and the neighbouring countries as Cheddar has in the Commonwealth and America. It is known as domestic Swiss in the United States. The cheese originated in Canton Berne in the valley of Emmenthal, and can be traced back to the fifteenth century at least. It was exported in the seventeenth century, and in the eighteenth made in France under the name of Gruyère. It is now made all over the world. It forms the greater part of Swiss cheese manufacture and is also made over large areas in France and northern Italy. The best of the Swiss cheese are exported, about 20 million lb. annually going to the United States. Emmenthal is a hard-pressed rennet cheese made from cow's milk and has a mild sweetish flavour. The characteristic feature is, of course, the holes or " eyes " which vary from ¼ in. to 1 in. in size and should occur from 1 to 3 in. apart. These are the result of the propionic acid fermentation in the cheese. The propionic acid bacteria produce propionic and acetic acid, and carbon dioxide or carbonic acid gas. Being a hard-pressed cheese, the gas cannot escape and so forms the characteristic holes.

In Switzerland the cheese is made from mixed evening's and morning's milk. An interesting feature of its manufacture is the use of home-made rennet. Commercial rennet is now used for cheesemaking in all civilised countries, but before the advent of such trade preparations cheesemakers had to prepare their own rennet. This is not actually a difficult task, for rennet can be obtained by soaking the fourth stomach of a young calf in brine. Home-made extracts are usually much weaker than the trade preparations and on account of the high degree of bacterial infection are more likely to give a variable product. The milk is sometimes inoculated with a pure culture of lactobacilli. The more up-to-date manufacturers use not only a lactobacillus culture to check the growth of other undesirable bacteria, but also a culture of propionic acid bacteria. The cheese may be as much as 4 ft. in diameter and weigh from 60 to 220 lb. The normal ripening period is from 6 to 10 months.

FORMAGGINI. This term includes several varieties of small Italian soft cheese. They are usually cylindrical in shape, weigh about 2 oz., and are consumed at practically all stages of ripening, salt, pepper, sugar, cinnamon, and sometimes oil and vinegar being added. They are usually made from cow's milk mixed with goat's milk.

GAMMELOST. A Norwegian sour skim milk cheese.

GERÔME CHEESE. A soft rennet cheese closely resembling Munster and made in the Vosges region of France. It is usually made from cow's milk, although a little goat's milk may be added. During ripening it is treated with warm salt water to prevent the growth of moulds. The size varies from ½ lb. up to 5 lb. and the ripening period from 6 to 16 weeks. This cheese is usually greenish when properly ripened.

GERVAIS CHEESE. A popular French soft cheese, this is usually made from two parts of whole milk and one of thin cream. It stands nearly 3 in. high and 2 in. in diameter and may be eaten either fresh or ripened. It is usual to make twelve cheese at a time in small hoops fixed on one base. For every twelve cheese required, 2 quarts of fresh warm milk and 1 quart of cream are mixed together by very thorough stirring. The mixture is then renneted at the rate of 1 ml. per gal. and at a temperature of about 75° F., which should be maintained until coagulation is complete. This usually requires 4 hr. The curd is then ladled into a coarse draining-cloth and hung up to drain in a warm room, the cloth being scraped at intervals. When the curd is sufficiently firm it is salted and then filled into the hoops, which are lined with strips of a special type of blotting-paper. Gervais is mostly eaten fresh, but it will keep for several days should the preference be for a ripened cheese.

GLOUCESTER CHEESE. Made chiefly in the Berkeley district of Gloucestershire. Two types are known : Double Gloucester and Single Gloucester.

Double Gloucester. A cheese closely resembling Cheddar, but the flavour is milder, little difference being perceptible in body and texture. Each cheese requires 28 gal. of milk, and from 0·25 to 0·50 per cent. starter should be used. The milk is renneted at 84° F. at an acidity of 0·19 to 0·20 per cent. If it is desired to make a coloured cheese, 1 dram of annatto may be added for every 2½ gal. of milk. Rennet is added at the rate of 1 dram to 3½ gal. and cutting takes place from 45 to 60 min. after renneting. When scalding, some makers remove part of the whey at intervals, heat it to 120° F. and then return it to the vat, the temperature being gradually raised to 94° to 98° F. in from 40 to 50 min. After milling, the curd is stirred to reduce the temperature to 80° F. and then salt added at the rate of 1 oz. to 3½ lb. curd. The hoop or mould used is about 9 in. high and 14 in. in diameter. Pressing occupies 2 days, after which the cheese is placed in the ripening room and care taken to exclude draughts. Some makers protect the new cheese with sheets during the first fortnight. The cheese are turned daily during the first 2 months and afterwards on alternate days. They are ready for marketing in from 4 to 6 months.

Single Gloucester. This is a quick-ripening variety and is made in some districts in the spring. The body is softer and the texture more open than in the other variety. It is different in shape, being but 3 in. high and 15 in. across. Some authorities consider that Single Gloucester is very suitable for toasting.

Each cheese requires 15 gal. of milk and starter is added at the rate of about 0·2 per cent. About 1 dram of rennet for 4 gal. of milk is used. Scalding takes place at a temperature of about 88° F. in summer and 94° F. in spring and autumn. About 1 oz. of salt is used for 4 lb. of curd and special care must be exercised in filling the moulds, which are usually made of heavy wood. Single Gloucester is ready for marketing in about two months.

GOAT'S MILK CHEESE. There are many varieties of goat's milk cheese and frequently they are unnamed. In France, they are commonly called Chevret or Chevrotin, in Germany Ziegenkase, and in Italy Formaggio.

GORGONZOLA CHEESE. As with other blue-veined cheese, two types of Gorgonzola are known, the green or fully ripened variety, which is much more important, and the white or unripened variety. Both are made from cow's milk. Gorgonzola was known as long ago as 1200 and is named after the village of Gorgonzola near Milan. It was formerly made almost exclusively by the shepherds of Lombardy, who took their flocks from the plains to the Alpine pastures, but is now made in several provinces. The cheese is cylindrical in shape, about 8 in. high and 10 in. in diameter, and may weigh 18 lb. or more. It has a hard rind, which is reddish in colour, due to the artificial dressing used for cheese that are to be exported.

Gorgonzola is prepared from two curds made from the milk of two different milkings. The afternoon milk is filtered and coagulated at a temperature of about 90° F., and at an acidity not exceeding 0·18 per cent. Coagulation requires about twenty minutes and the curd is then cut with a skimmer to pieces about 1 in. in size. It is left to settle and the pieces of curd are collected in an open-mesh cloth, each cloth containing the curd from about 8 gal. of milk. The cloth is then hung up to let the whey drain. The second curd is prepared similarly from the following morning's milk and left to drain for half an hour. The hoop or mould is placed on a layer of straw or matting on an inclined board. A cloth is inserted and the curd cut into pieces about 2 in. × 1 in. and placed in the hoop alternatively from each curd, *i.e.* first the warm morning and then the cold evening curd, the first and last layers being made with the warm morning curd. This arrangement is characteristic for the Gorgonzola process. The curd is then covered with a cloth and the hoop turned every few hours to obtain a good drainage. The cheese is turned twice a day for the next few days, the temperature of the draining-room being 60° to 70° F. After 3 or 4 days a slight mould growth appears on the surface and the cheese is then ready for salting. Salt is first finely powdered and then rubbed on the upper surface and round the hoop and afterwards on the base. The cheese is again salted after 2 days and in 4 or 5 days is firm enough to be taken out of the hoop and salted all over. The larger sizes are salted twelve times and ordinary sizes ten times, the dry salting lasting from 20 to 24 days.

At this stage the cheese is sold to a specialist who takes care of the ripening process, which consists of three stages, drying, ripening, and storage. Drying takes place in very dry and well-ventilated rooms which are maintained at a temperature of 55° to 60° F. and at a humidity of 75 to 80 per cent. During this time the cheese are turned every few days and carefully scraped. Sudden changes must be avoided, and usually the cheese takes on a whitish colour with reddish tinting. This drying process takes from 20 to 30 days. The ripening proper may be carried out in natural caves or in artificial ripening stores, which are usually near the production centres. There are two stages in the ripening process, the first being at a temperature of 48° to 52° F. and a humidity of 85 to 90 per cent., and lasting about one month. The development of the moulds may be accelerated by perforation of the curd and by the addition of mould to the milk. During this period the cheese must be turned and scraped in order to prevent the exterior from becoming mouldy and the interior from cracking. Towards the end of the first stage the cheese becomes yellowish. The second stage takes place at a temperature of 42° to 46° F. and a humidity of 90 per cent., and lasts about two months. The surface becomes reddish and the curd yellowish with abundant markings and there is also a tendency to crack. When the characteristic sharp taste is present the cheese is fully ripened and put into storage. The storage rooms have a low temperature (40° to 44° F.) and a high humidity (90 to 100 per cent.).

Cheese intended for export receive a somewhat different treatment. Thus they may be wrapped in tinfoil or some other material suitable for maintaining the cheese in good condition. As with Roquefort and Stilton, the preliminary ripening carried out by lactic acid bacteria and the rennet enzymes is succeeded by the growth of the blue mould which by its action on the fat and protein produces the characteristic peppery flavour. There is also on the outside of the cheese the reddish growth of different bacteria which are supposed to contribute to the ripening. Formerly the cheese were only ripened in those places where natural caves were available as at Roquefort, but with the advent of artificial caves the ripening is now largely carried out under artificially produced conditions. These artificial caves may contain up to 60,000 cheese and always have controlled temperature and humidity. They are placed below the level of the road and are supplied with long deal shelves arranged in tiers.

One hundred gallons of milk will yield from 130 to 150 lb. of immature cheese and from 100 to 120 lb. of ripe cheese. There is thus a loss of from 15 to 30 per cent. during ripening. Gorgonzola cheese should contain at least 40 per cent. fat in the dry matter and from 50 to 56 per cent. of moisture, depending on the age of the cheese.

The white Gorgonzola is made quite differently; it uses only one curd and is submitted to a forced fermentation by the application of heat. It is only exported, however, to Germany, Austria, and Poland.

GOUDA CHEESE. This is a Dutch cheese made from the whole milk of cows, chiefly on the farms of Zud Holland and Utrecht. It is shaped rather like a Derby, but has rounded edges and may weigh from 6 to 44 lb.

In making Gouda a little colouring matter is added and after raising to 86° F., sufficient rennet added to the milk to obtain a curd ready for cutting in half an hour. Formerly a wooden instrument was used but now the ordinary American knife is employed. The curd must never be roughly handled. After stirring, the whey is run off and hot water poured on the curd to heat it up to 90° F. and then, after about an hour, to 100° F. When sufficiently dry the curd is moulded without salting and the cheese then pressed with up to ten times their own weight. After pressing, the cheese are salted by immersion in brine. Salting continues from 2 to 6 days and the cheese is then placed in the ripening room. Ripening requires from 6 to 8 weeks. Another type is made from partly skimmed milk in factories and the method of manufacture is modified accordingly. The full-cream variety must have a fat content of at least 46 per cent. in the dry matter and has, in fact, usually about 50 per cent. The factory variety may contain from 20 to 40 per cent. in the dry matter, and this is guaranteed by the Government mark.

"GREEN CHEESE." The term *green* is usually applied to hard pressed cheese in the early stages of ripening before the characteristic aroma and body of the ripe cheese have developed.

GRUYÈRE. Emmenthal type cheese made in France is called by this name, which originates from the Swiss village of Gruyère. It may be made from whole, partly-skimmed, or skimmed milk, but whereas Emmenthal is or should be made from whole milk, Gruyère is usually made from partly-skimmed milk. About 50 million lb. are made annually in France. A surface slime appears on this cheese (but not on Emmenthal) and is supposed to play some part in the ripening. The method of manufacture now differs from that of Emmenthal.

KNAPOST. *See* Pultost.

KOSHER. A Limburger type made under certain supervision for Jews. *See* p. 197.

LACTIC. A general name for sour milk cheese made from whole or skim milk which may or may not be processed. If the former, cultures of *L. bulgaricus* or other similar organisms may be incorporated.

LANCASHIRE CHEESE. Although not well known outside the county of its origin, it is in great demand in Lancashire, especially in the industrial areas of the south, and is reckoned an excellent cheese for toasting. The toasted cheese, "Leigh Toaster", has a custard-like texture and an appetising aroma. Lancashire is appreciably softer than the cheese already described, and difficulties of transport restrict its popularity. Thus, when 3 months old it is so soft that it will spread like butter. The method of manufacture differs in some important details from the methods for hard-pressed cheese. Perhaps the most characteristic difference is that the curd of one day's make is held over and mixed with that of the following day's milk. The mixing of curds at different acidities and stages of development results in a cheese possessing a loose and soft body. It is made in three sizes, two having a flattish shape (diameters of about 10 and 14 in. and weighing about 30 and 50 lb. respectively) and the other smaller ("loaf") weighing about 10 lb. Owing to the high moisture content of this cheese, about 1¼ lb. of cheese is obtained from each gallon of milk. There is, however, an appreciable loss during the ripening process, the loss being about 10 per cent. in the first 3 weeks and a total of about 15 per cent. in 3 months.

Both evening's and morning's milk are used and about 0·25 per cent. starter is added after the morning's milk has been put in the vat. A special type known as a " Gornalls " vat, which is a revolving cylinder having a perforated section of the curved surface, may be used. This is used as a lid and also permits the drainage of the whey. After warming to renneting temperature, which may be 84° to 88° F., the milk is left to ripen for about half an hour. Renneting takes place at a very low acidity, being only 0·005 per cent. above that of the evening's milk. Cutting takes place after about an hour and the curd is then allowed to settle until the acidity has increased by 0·005 per cent. Lancashire cheese curd is now scalded in some factories. The drainage of the whey may take up to 1 hr. and it is important that it should not be hurried. The curd is next lifted by a scoop into the drainer and tied up in a cloth. Increasing pressures are applied, and the curd repeatedly cut into blocks and broken into pieces. When ready for grinding, the curd should be moderately firm and dry, and sweet to the taste. Too dry a curd will result in an insipid, loose-textured cheese ; too wet a curd in one that will be sour. A portion of the curd is now set aside for use next day, and should be held at a temperature of 65° to 70° F. The proportion of new curd to old depends on the acidities of the curds, their age, and the time of the year. The mixed curd is ground until it is as fine as chopped suet, and salt incorporated at the rate of 1 oz. to 3½ lb. curd ; the temperature should not fall below 70° F. at this stage. The curd is next filled loosely into moulds and in the evening these are turned into fine cloths, replaced in the hoops, and the next morning pressure applied. After pressing, the cheese is removed from the mould, bandaged, pressed for a further 12 hr., and then placed in a well-ventilated room. When the bandage is dry, the cheese is bathed in hot whey, butter, or lard, which is usually coloured with a little annatto. The cheese may be ripened either quickly or slowly. In the former case the temperature should be 62° to 65° F., when it ripens in from 3 to 5 weeks; in the latter case the cheese requires 6 months at a temperature between 55° and 60° F. Lancashire cheese is much more open in texture than the harder varieties such as Cheddar ; it is also appreciably softer, *i.e.* it contains more moisture, so that the body is generally described as soft and silky. The flavour is mild and slightly acid during the first two months of ripening. It is a relatively short-keeping cheese, but a long-keeping variety has been made during the war.

LEICESTER CHEESE. As in the case of Lancashire, this cheese is neither made nor well known outside the county, although it is a cheese that deserves to be much better known. It is characterised by its bright colour and good keeping qualities. In size it is some 4 in. high and 18 in. in diameter, and weighs about 40 lb. The cheese is flaky and loose in texture, rather soft in body and rich in flavour.

Leicester cheese is made from mixed evening's and morning's milk, which should be as clean as possible and well cooled, as the high colour of the cheese makes it very liable to faults produced by colour-bleaching organisms. One dram of annatto is used for every 2½ gal. of milk, which is then raised to a temperature of about 85° F. and 0·25 per cent. starter added. The milk is renneted at an acidity of 0·19 per cent., 1 dram of rennet being used for every 3 gal. of milk. The curd should be firm enough for cutting about 50 min. after renneting, when it is cut fine and scalded for ½ hr. at about 95° F. When an acidity of about 0·13 per cent. has been attained, pressure is applied to the curd in the vat, the whey being finally run off when the acidity reaches 0·14 per cent. Too high an acidity leads to hardness and poor texture. After running off the whey the curd is cut into 3 in. blocks, which are piled in the vat under slight pressure. At the end of about 2 hr. the curd should be soft and open ; it is finally ground very fine, well stirred and salted at the rate of about 1 oz. to 3 lb. curd. The curd is now much firmer and is filled into the mould. Only very light pressure is applied at first, but this is gradually increased to 20 cwt. The following day the cheese is greased and calico caps fitted, and on the third day taken out of the mould and a bandage pasted on it. Leicester cheese require particular care during pressing and ripening, as rough handling leads to cracks and the development of black mould. It is advisable to ripen in a dryish room for the first few weeks, and when the cheese is dry it can with advantage be removed to a cellar or other suitable room with low temperature and fairly high humidity. About two months are required for ripening, and the bandage should be removed for the last fortnight in order to permit blue mould to develop on the surface.

LIMBURG (BACKSTEIN) CHEESE. A soft cheese made from cow's milk. Although it is sometimes made from partly or even entirely skimmed milk, the best is undoubtedly made from whole. It weighs about 2 lb. and is about 6 × 6 × 3 in. high. It has a powerful and characteristic aroma. The cheese was originally made in the province of Luttich and was marketed in Limburg, Belgium. It is now extensively made in Germany and Austria and also in America.

In making Limburg, rennet is added to sweet milk at a temperature of about 94° F. and the milk coagulates in about forty minutes. On the Continent a kettle is used, but an ordinary rectangular vat is quite satisfactory. The curd is cut into cubes about one-third inch in size and stirred without heating. It is then put into rectangular moulds or hoops on a draining-board where extensive drainage takes place. When the cheese is of such consistency as to retain its shape on handling, it is removed for salting, which is carried out by daily rubbing with salt. When the coat begins to get slippery, the cheese is removed to a ripening cellar at 60° F. During ripening, which lasts from 4 to 8 weeks, the surface must be rubbed thoroughly. Finally, it is wrapped in paper and tinfoil and packed into boxes containing about fifty cheese.

MUNSTER CHEESE. Made from the whole milk of cows in the region of Munster, West Germany. A similar cheese is made under the name of Gerôme in that part of France which adjoins this region.

MYSOST, MYSEOST. A Scandinavian whey cheese of a light-brown colour (this varies), a buttery consistency, and sweetish in taste.

NEUFCHATEL CHEESE. A soft cheese made from whole or skimmed milk. Many very similar cheese are made in France under such names as Petit Suisse, Bondon, Petit Carré, etc. They usually differ somewhat in shape. The method of manufacture closely resembles that of cream cheese but less rennet is used. In its standard shape the cheese is round, wrapped in tinfoil and weighs nearly 3 oz.

PARMESAN CHEESE. The characteristic feature of this cheese is its extreme hardness. For this reason it is almost impossible to cut, has excellent keeping properties, and will last for years. It is frequently grated and stored in bottles. Two varieties are made, one in Lombardy and the other in Emilia. The name is derived from the town of Parma in Emilia, although the term Reggian is sometimes used to denote cheese in Emilia. In Italy it is commonly referred to as " Grana ", on account of its granular appearance when broken. The Reggian type, which is only produced in the summer, is made from a richer milk, is coloured, and commands a much higher price than the Lombardy-made cheese. After the removal of more or less of the cream the milk is heated in copper kettles to about 95° F., the exact temperature depending on the acidity of the milk. The kettle is then taken off the fire and the milk renneted. After standing for from 20 to 60 min. the curd is cut very fine and scalded with stirring to 115° to 125° F. for 15 to 45 min. After removal from the kettle, the curd is drained for a short time and then filled into moulds or hoops 10 in. high and 18 in. in diameter. The cheese are then pressed for 24 hr. and salted, a process which may continue for some time, *e.g.* 40 days. The cheese are next placed in a cool airy room and rubbed with oil from time to time, the dark green or black colour of the cheese being due to colouring matter rubbed on the surface. They may be stored in this way for years. When grated it is commonly used in soups and for eating with macaroni. The exported product commands a high price.

Pecorino Cheese. A general name applied to cheese made from sheep's milk in Italy, the most common variety being called Romano. These cheese vary considerably in size and shape, and may weigh from 2 to 25 lb. The milk is renneted at 100° F. and cut after 15 min. After scalding at 120° F., the curd is put into moulds and allowed to drain. Salting may be carried out either by rubbing or by brine immersion. The process is sometimes accelerated by making small holes in the cheese, but this has been found to cause moulds to grow in the interior and so should not be done. The cheese are ripened for at least 8 months at a temperature of 60° to 70° F. They are usually slightly greenish internally and somewhat granular, but should be free from holes.

Pommel. A characteristic, small French soft cheese.

Pont L'Eveque Cheese. A variety fairly well known in England and different from Camembert. Thus ripening by moulds is not so marked a feature in Pont L'Evêque. The cheese are rectangular in shape, about 1¼ in. thick and weigh about 1 lb. The ripened cheese is soft and elastic and reddish brown in colour. The taste is like that of a sweet, very soft Edam. Perfectly sweet milk must be used in the manufacture, for the presence of any acidity results in a hard dry cheese. Five gallons of milk will make six cheese. The milk should be strained into a wooden tub and 1 dram of rennet added for each 2 gal. at a temperature of about 92° F. The milk is then stirred carefully and kept warm. After 30 to 40 min. the junket is ready for cutting. After the curd has been cut in small sections these are cut horizontally with a flat scoop and the curd ladled into warm straining-cloths held on wooden supports over a draining-table. The cloth is not tied up and the temperature should be maintained by spreading warm dry cloths over the surface of the curd. Drainage is complete in about one hour, when the curd should be approximately one-third the quantity of the original milk. Half an ounce of salt per cheese is mixed in and then the cheese moulded. At this stage it should be rather soft and flaky. It is important to obtain a close surface by the correct method of packing the moulds and by frequent turnings as otherwise the cheese are spoiled by excessive drainage. They are turned everyday for 3 days and then removed from the moulds and their edges scraped. On the fourth day they are put in the ripening cellar, which should be at about 55° F. After about sixteen days the cheese are packed together in triple layers in order to minimise loss by evaporation and their positions changed to secure uniform ripening. At the end of 5 or 6 weeks the cheese should be ripe and soft but not creamy. Good cheese usually bulge slightly at the sides and when cut should not show different ripening levels. It will be evident that Pont L'Evêque are not so moist as the other soft cheese described and they have much better keeping qualities. They are packed singly in light boxes.

Port du Salut Cheese. May be regarded as a semi-hard variety, for, although possessing a strong rind, the interior is soft but does not become semi-liquid, like Brie for example. It is supposed to have originated in 1865 in the Trappist Abbey of Port du Salut in the Department of Bayenne, France. Although the monks claim that the process is a secret one, very successful imitations are now made. The following method is usually adopted. Milk is warmed to about 92° F. and sufficient rennet added to enable cutting to be done in half an hour. A slight acidity is desirable and a little colouring matter is usually added. The method of cutting closely resembles that used in making Emmenthal. After removal of part of the whey the curd is scalded up to about 104 F., allowed to pitch and the whey run off. The curd is then put into hoops and pressed. The following day the cheese are salted and after drying for a further day transferred to the ripening cellar for about six weeks. A temperature of 55° F. and a humidity of nearly 90 per cent. are most suitable. The cheese are washed with salt during ripening to stop mould growth and may be sold before the ripening process is complete. Due to the fact that it has been so widely imitated, the name *Saint Paulin* has now been registered by the " bona fide " makers.

Potato. A German sour milk curd to which boiled, mashed or grated potato has been added.

Primost. *See* Mysost.

Processed Cheese. A product prepared by melting Cheddar and other types of cheese, usually the hard-pressed varieties, and emulsifying them with salts, especially citrates and phosphates, and often water, whey powder or paste, etc. The mixture is heated to kill most bacteria present and so, after wrapping in foil, has a long keeping quality and remains moist and attractive. During the war and since, only third and no-grade cheese have been used for this treatment.

Pultost. A Norwegian sour milk cheese in which a high scald temperature is used. Also called Knapost.

Quarg. A general name for a crude sour skim milk curd cheese usually eaten unripened.

Roquefort Cheese. One of the most famous of all cheese ; genuine Roquefort must be made with sheep's milk and ripened in the caves at Roquefort. It is probable that small amounts of milk from other animals are sometimes mixed with the sheep's milk. There have been numerous imitations of this cheese and these are commonly given self-explanatory names, such as Danish Roquefort which is made from cow's milk. Roquefort cheese has been made in the south-east of France for at least 200 years and is also made in Corsica. In making Roquefort the milk should be adjusted to about 79° F., which is done in practice by heating part of the milk to a much higher temperature. About an hour and a half after renneting the curd is cut into pieces the size of a walnut. After dipping off the whey the curd is put into moulds about 8½ in. across and 3½ in. high. During filling, two layers of mouldy breadcrumbs are worked into the curd. The cheese is not pressed and may therefore be regarded as a soft cheese. A considerable proportion of Roquefort is now made in factories, but formerly the cheese were made by the shepherds. In both cases the cheese are taken to the caves for ripening. These are numerous in the district and are advantageous on account of their low temperature (40° to 45° F.) and high humidity. Of late, artificial caves have been constructed. After making, the cheese are salted, rubbed vigorously with a cloth, and finally scraped with knives, which may be done by hand or by machinery. These combined treatments serve to inhibit the growth of moulds on the surface. To accelerate the growth of moulds in the interior of the cheese, they are pierced by a number of small needles (20 to 60), using a special appliance. Some cheese are sold quite early, *e.g.* in one month, but they should remain in the caves for about five months to attain the full extent of ripening. When ripe a cheese weighs nearly 5 lb. and has lost nearly 20 per cent. of its original weight.

Roquefort made from cow's milk may be considered as a distinct variety and has in fact been recognised as such since 1918. The earliest attempts failed on account of the too rapid drying of the cheese during ripening. These faults have been avoided by careful regulation of humidity and the use of tinfoil during ripening. Direct expansion coils in the ripening rooms are frequently used to keep down the temperature. One effect of using cow's milk is that a somewhat more yellow cheese is obtained and to counteract this winter's milk is often used. Slight modifications in the process of manufacture are observed but the essential details are the same as when using sheep's milk. It will be evident that the manufacture of Roquefort requires special equipment and care in ripening. It is not, therefore, a cheese which can be made with profit on a small scale. Roquefort is about 4 in. high, 8 in. across, and weighs about 4 lb. The ripened cheese are usually wrapped in parchment and tinfoil, and, if exported, packed twelve in a box. Similar cheese have also been made from goat's milk, which resembles sheep's milk in colour. The flavour is characteristic of the animal from which the milk is obtained. In the early stages of ripening the sheep's and goat's-milk cheese possess a high flavour which is objectionable to some people. This is, however, destroyed or submerged by the later ripening processes.

SAGE, SPICE. Derby or other similar cheese containing sage or other spices.

SAINT PAULIN. *See* Port du Salut.

SINGLE-CREAM CHEESE. As its name implies, it is made from thinner cream than double-cream cheese. It is, therefore, poorer in fat, but has a more marked cheesy flavour and is made from cream containing from 25 to 30 per cent. fat. The choice depends mainly on personal preference. About twenty-four ¼ lb. cheese can be made from 1 gal. of thin cream. The cream is cooled to 65° F., four drops of rennet per gallon of cream added, and also a little starter just before the cream is cooled, and the whole left for 8 or 12 hr. before draining. If salt is to be added, it should be added with the rennet. The curd is lifted into a cloth by means of a ladle. The methods used for draining and moulding are the same as those for double-cream cheese. Single-cream cheese naturally sell at a lower price.

The essentials of cream cheesemaking are a sweet cream carefully cooled and ripened at a low temperature, the addition of salt to the cream and not to the curd, the use of fine dry cloths in which to drain off excess moisture, spreading the cream in a layer not more than 1½ in. deep in the drainage form, and, finally, slight pressure during the first stages, slowly increasing up to 14 lb. Cream cheese are particularly liable to become tainted on account of the high proportion of fat. It is important, therefore, that all materials used should be absolutely clean.

SOFT CHEESE. These have not been so well taken up by the public as the hard-pressed varieties. On the Continent, however, especially in France, innumerable varieties of soft cheese are made. Many of them do not differ essentially from the other, but all have delicate and appetising flavours. The success of the French varieties has been attributed to the climate, but there seems to be no good reason why equally successful soft cheese should not be produced in England. It has been claimed that quite as good cheese can be produced in the south of England, especially in those districts which enjoy an equable climate. Soft cheese ripen rapidly and perhaps appeal more to persons with discerning palates. Their manufacture is, therefore, most suitable for small farmers and others near big towns and fashionable resorts. The chief difficulty in making is controlled ripening, for without this it is impossible to obtain a uniform product. It is essential that the maker should have at his disposal at least three rooms whose temperatures and humidities can be controlled. Soft cheese are not pressed, are usually small, and on account of their high moisture content they ripen quickly and can often be spread on bread like butter. The curd is usually formed from sweet milk, and the acid is formed in the milk after the rennet has been added, or in the junket during the draining process. The method of making is thus strongly contrasted with that of hard-pressed cheese. The whey is never fully drained from soft cheese curd, and neither heat nor pressure is used to assist in the expulsion of moisture. The rate of ripening is controlled to a considerable extent by the moisture, for not only can the rennet enzymes act more rapidly in the presence of larger amounts of water, but many types of micro-organisms which cannot grow in the dry, acid, hard-pressed cheese, do so comparatively readily in soft cheese. These organisms not only assist in the ripening, but also cause faults much more easily than in hard-pressed cheese. The strong flavours in cheese, such as Camembert, are due to this fact, and many varieties depend for their ripening upon the growth of moulds on the surface of the cheese. These moulds can only grow on the surface because they require air, but they can, however, produce enzymes or digestive juices which penetrate a cheese and bring about the changes associated with ripening. The flavour and texture of some types cannot be produced without the growth of the right mould on the surface, and in such cases the ripening proceeds from the surface inwards. In hard-pressed cheese, the interior ripens more rapidly on account of the greater rate of evaporation in the outer portions of the cheese. In soft cheese, therefore, the raw curd is changed into the soft, buttery, ripened cheese most rapidly near the surface, and the process is complete in about a month. The growth of the mould is favoured by an acid curd, and it is necessary for this purpose that a certain acidity should be obtained before the salt is added, as salt inhibits the formation of acid by the acidifying bacteria. When starters are used there is a tendency for the acid to develop too rapidly in the early stages, with the result that a hard, dry curd is obtained and the moisture content is too low for the growth of the mould. It is essential to use very clean milk for soft cheese, and if there is the slightest doubt of the hygienic quality of the milk it should be flash-pasteurised. It is sufficient for this purpose to raise the temperature of the milk to 150° F. The milk is then cooled to the renneting temperature and one drop of starter may be added to each gallon of milk before renneting. If the milk has received more severe heat-treatment, it may clot less readily with rennet and it will be necessary, therefore, to add slightly more rennet at a temperature a few degrees higher than normal.

STILTON CHEESE. The best known of our mould-ripened cheese and usually regarded by connoisseurs as the queen of British cheese. The demand for this variety has somewhat decreased of late, primarily owing to changes in the conditions of living of those who formerly were the chief consumers of Stilton. This is a great pity, for Stilton is a cheese of which we have every reason to be proud, and its consumption could with advantage be increased tenfold. Perhaps more experience and skill are required to produce a really first-class Stilton than any other cheese. The proportion of such cheese in the output of even a first-rate maker is smaller than for other types. This is because more factors are concerned in the ripening of Stilton than in the non-mould-ripened varieties. The mould which develops in Stilton and causes the characteristic blue veining or marble effect grows during the later stages of ripening, when changes in the structure of the cheese produce cracks and fissures and so permit the entrance of air. Unlike most bacteria, moulds require air for growth. This is the reason why moulds do not grow in the interior of properly made Cheddar and similar types. There has lately been an increasing demand for the so-called " white Stilton ". The white Stilton is the ordinary Stilton which has not developed mould growth and is thus not ripened.

It is believed that in the early history of Stilton making it was prepared from uncooled morning's milk and the cream of previous evening's milk. The effect would be, of course, to give a milk of high fat content and a cheese of marked richness and mellow character. At a later stage the method of using curds of different makes was employed. In this process, curd prepared one day would be mixed in with the curd of the following day's make. The effect of this would be to produce an open texture, allow more air to penetrate the cheese and so promote the growth of the blue mould, *Penicillium roqueforti*. This method had certain disadvantages, however. Thus, on cutting, the two curds would show different colours, especially if one was from morning's and the other from evening's milk. Difficulty was also experienced in controlling the acidities of the two curds.

Present Method of Manufacture. In general, it may be said that the sweeter or less acid the cheese that is made, the more important it is that the milk should be as free from bacteria as possible. This is because fault-producing bacteria are inhibited by acid. In Stilton-making a clean milk supply is of first importance. The milk should preferably not be cooled, and 1 dram of rennet is used for 4 gal. of milk at a temperature of about 85° F. Coagulation requires from 60 to 70 min. The junket is considerably softer than that produced in making hard cheese and requires careful treatment. The characteristic feature of Stilton-making is the ladling of the curd. The receptacles for receiving the ladled curd are prepared by laying wooden laths across a sink at intervals of about 18 in. Bags are prepared by placing damp cheese-cloths over the laths. The cloth thus acts as a strainer, retaining the curd while the whey collects round the bags, thereby assisting in the development of acidity and keeping the curd warm. When the bags are full they are formed into bundles by folding over the ends of the cloth, and left in the whey until about 0·12 per cent. acid has formed. Some of the whey is then run off and more whey allowed to ooze out of the bundles. After about an hour the process is repeated, and when the acidity has reached about 0·17 per cent. the bundles are turned over. The acidity should progress uniformly; a falling off in the rate of acid production may result if the drainage process is long-drawn-out or if the temperature falls. At an acidity of 0·2 per cent. the curd is turned out into the sink, and the acidity should develop sufficiently slowly so that it can be left overnight. When a suitable acidity has been reached, the curd is broken into pieces about 1 in. in size and salt added at the rate of 1 oz. to 3 lb. curd. The salt should be allowed to dissolve thoroughly before the next operation. The filling of the hoops is started with the smaller pieces of curd, which are lightly pressed down by hand; the larger pieces are then placed in the middle and smaller ones on the outside. This assists in the production of the right texture, and lays the foundation for the forming of the coat. The temperature of the curd at this stage should not be less than 62° F. Drainage takes place on calico squares laid on boards, and the boards and the cloths are changed daily for about ten days, the temperature being maintained at 62° F. The cheese are now shrunk sufficiently to allow the moulds to be slipped on and off quite easily, and the sides of the cheese become quite greasy. The next stage is to scrape the surface of the cheese and fill the scrapings into the crevices, which materially helps in the formation of the characteristic Stilton coat. A calico bandage is then pinned tightly round the cheese, which is replaced in the mould. The cheese is later rescraped, this time lightly; too drastic a scraping will result in a thick, heavy coat which is no longer fashionable. After bandaging, the cheese are placed on the draining shelves and turned daily and rebandaged until a coat shows signs of forming and dry patches appear on the bandage. When a fine white mould begins to grow the bandage may be removed. Careless handling of the cheese must be avoided, as the ripening process is largely dependent upon the coat, the best conditions for the formation of which are a low temperature and a high humidity. The cheese should still be turned daily and when a good coat has formed they may be removed to the ripening cellar, which should have a temperature of about 58° F. Ripening requires up to 6 months, depending on the size of the cheese and the temperature and humidity of the ripening room. As in the case of other cheese, the best Stilton are produced when the ripening takes place most slowly. A blue-veined cheese of a sort can be produced in 6 weeks, but this time does not allow of the proper sequence of changes which are necessary for the production of the true Stilton flavour. The growth of mould in any cheese depends on the amount of air that can penetrate the cheese, consequently Stilton can only "blue" when cracking takes place in the curd. Many makers of blue cheese, therefore, now "prick" their cheese by stabbing with a knitting-needle or similar instrument. In this way a small passage is made which allows the entrance of air more rapidly than would otherwise take place. Although this method does in fact increase the extent of mould growth, some authorities consider that the idea has been rather overdone, and that pricking has resulted in a blue-veined cheese with properties not quite the same as those of the true Stilton.

Stilton is made in two sizes, one weighing 10 lb. and the other 16 to 18 lb., which is more commonly made for the London market. A good Stilton should be evenly veined throughout the interior and the coat should not be too thick. Really good Stilton will always find a market at a good price, the demand coming chiefly from clubs and hotels. Second-quality Stilton, however, suffers in competition with Gorgonzola. This state of affairs is rather similar to that between second-grade farmhouse Cheddar and the Dominion products. Stilton-making is attended by considerable risks and expense. If the maker can produce at least

60 per cent. of first-grade cheese his business should be run at a profit. On the other hand, a high percentage of poor cheese will result in a heavy loss. Variations in quality are more frequent with Stilton than with any other common cheese. Recently there has been an attempt to make Stilton in Holland, but, as is usually the case with such endeavours, the Dutch product cannot be considered a true Stilton. The cheese are made chiefly in the Melton Mowbray district, and the prize Stiltons at the shows usually come from this area. It is generally held that first-quality Stilton cannot be made in other localities. This may be true, but no definite reason can be assigned to it. The name "Stilton" is derived from the fact that the cheese were originally dispatched to London by coach via "The Bell" inn at Stilton in Huntingdonshire. Stilton cheese were not made at Stilton.

STRACCHINO. Various types of Italian soft cheese.

TILSIT CHEESE. This is an East Prussian hard-pressed cheese made from cow's whole milk. The milk is renneted at a temperature of 92° F. and the curd cut rather coarsely about thirty minutes later, and scalded at about 104° F. for 40 min. After moulding, it is first salted externally and then by immersion in a brine bath. During ripening, which occupies about five months, it is frequently washed with brine. A cheese may weigh from 6 to 28 lb. and resembles the American Brick cheese.

TRAPPIST CHEESE. It is probable that this cheese was first made by the Trappist monks in the Monastery of Mariastern in Bosnia. For all practical purposes it is identical with Port du Salut. A similar cheese is made in the Trappist Monastery in Oka, Canada, and is there known as Oka cheese. Sometimes Trappist cheese is strongly flavoured and has gas holes.

VENDÔME CHEESE. This is a soft cheese of the Camembert type and is made chiefly in the region of Vendôme in France and marketed in Paris. Warm milk is renneted at about 80° F. and after about five hours the curd broken up and put into moulds about 5 in. across and 4 in. high. After draining for a day the cheese are salted several times and finally placed in the ripening cellar where they are sometimes buried in ashes.

WENSLEYDALE CHEESE. Although probably an old cheese, Wensleydale was comparatively unknown outside Yorkshire until recent years. It is, however, a cheese that deserves to be better known, and is now made all over the country. It resembles a Stilton in shape and has a grey-white skin when properly ripened; a smooth coat without bandage marks usually indicates a hard acid chee e. Good Wensleydale cheese will spread like butter and, like Stilton, has the blue veining evenly developed throughout the curd. The flavour should be rich and creamy. A small flat Wensleydale is also made which weighs approximately from 6 to 10 lb. It is sold before the blue mould has developed, when it is white, acid, and crumbling. It thus corresponds to the white Stilton and, like the latter, entirely lacks the characteristic flavour of a properly-ripened, blue-veined cheese.

In making Wensleydale cheese the evening's milk is cooled to 65° F. If this is not done the high temperature may lead to too high an acidity in the milk, which is a serious defect in this cheese. About 0·1 per cent. starter is added and the milk gradually heated to 84° F. When the acidity has reached about 0·18 per cent., 1 dram of rennet is added for every 4 gal. of milk used and the junket should be firm enough for cutting 1 hour later. Cutting must be done very carefully in order to prevent too rapid draining. Stirring should be done as little as possible, as the curd must be kept soft. The temperature is raised to 80° F. during the stirring, and when an acidity of 0·13 per cent. is reached the curd is allowed to pitch for ½ hr. and then the whey carefully run off. The curd is next scooped into cloths on a draining rack. When transferring the curd it is essential that it should be treated gently. The cloths are then pulled up to form bundles of cur and after 20 min. the curd is cut into blocks and again wrapped up. This process is repeated until the drainings show nearly

0·13 per cent. acid, when the curd should be showing signs of flakiness. This is usually after about three hours. Too rapid a draining rate and too fast a development of acidity will result in a dry crumbly cheese. The curd is finally broken up into pieces about 1 in. in size and salted at the rate of 1 oz. to 4 lb. curd. When the salt has completely dissolved, the curd is placed loosely in unlined hoops, the smallest pieces being put at the top and bottom. No pressure is used to assist drainage, and the cheese is kept overnight at 65° F. The next day the cheese is wrapped in a dry cloth and pressed for 2 hr. with about 6 cwt., after which a calico bandage is stitched on and the cheese put back to press for 2 hr. The most suitable ripening room is a cellar, as it is important to avoid warmth and dryness. The cheese has to be turned every day for the first 6 weeks and thereafter every other day during ripening, which requires about six months. It thus differs from Stilton in being lightly pressed and bandaged during ripening, and is somewhat closer in texture.

YORK. *See* Cambridge cheese, p. 186.

Analysis of Common Types of English Cheese.

Type	*Fat* (%)	*Moisture* (%)	*Fat in dry matter* (%)	*Salt* (%)
Cheddar	33·0	34·0	50·0	1·7
Cheshire .	31·5	36·0	49·2	1·9
Lancashire . . .	31·2	36·0	48·8	1·9
Leicester .	30·9	37·0	49·0	1·8
Stilton .	33·0	39·0	54·1	2·1

Manufacturing Records. In cheesemaking it is desirable to keep systematic and accurate records of the various stages in the process. Such records are chiefly concerned with times of the various operations, quantities of materials, acidities, and temperatures. The value of these lies not only in their purely business aspects, but also in permitting the detection of abnormalities in working. By comparing variations in manufacturing detail with the final grading of the partly-ripened product, it is possible to obtain much useful information for the manufacture of the most profitable type of cheese. Records thus have a great educative and research value.

The future will inevitably see more and more factory—and less farmhouse—making. It cannot be realised too strongly that factory-making is a very different problem from farmhouse, with its one supply of milk and fairly well-defined variations in behaviour. While records may be considered by some farmhouse makers an unessential part of making, it is quite the reverse with factory technique. There are many reasons for this, and perhaps the most important is the lack of continuity due to the transfer of personnel working at one vat to another. In addition, the use of heterogeneous milk supply which has not been produced under the supervision of the cheesemaker naturally increases the chances of abnormal working which careful records will reveal.

Records may be classed under two headings: (1) Those essential for the business side. (2) Those that are of assistance to the cheesemaker, and to the chemist and bacteriologist.

Essential data.

(1) Gallonage of milk
(2) Fat or total solids test of milk
(3) Price of milk and bonus (if any)
(4) Quantity of starter
(5) Quantity of rennet
(6) Quantity of salt
(7) Weight of curd at press
(8) Grading and price of cheese
(9) Weight at selling .

The above represent the minimum requirements from the purely business side.

Cheesemaking data.

(1) Times of all operations
(2) Temperatures at certain operations
(3) Acidities (by titration) at certain operations
} Usually recorded with above

(4) *p*H values during making
(5) Moistures during making
(6) Pitching number and other rheological properties
(7) Tests for protein breakdown
} Scientific tests in the experimental stage

Times and Temperatures. The only points that need be mentioned here are that all thermometers should be tested against a specially-kept thermometer known to be accurate over the range 80° to 110° F. and that times in relation to operations must be standardised. For example, it may take up to half an hour to run the whey from a 1000 gal. vat. Thus in recording the times of cutting, running the whey, etc., a standardised procedure must be adopted.

Titratable Acidities. While it is not imperative for cheesemakers to make accurate titrations in the chemical sense, it is essential for a reproducible and standardised method to be adopted. Moreover, the technique generally used in the early stages, for example, is so crude and the error so large, that pretending to measure acidities to 0·005 per cent. lactic acid (*e.g.* 0·125 per cent. at cutting) is absurd. Considerable errors occur in measuring the volume of milk or whey and determining the end-point. The following general procedure is recommended for all cheesemakers: Take a sample of the well-mixed milk or whey in a cup or dish and suck up 10 ml. (or 10 c.c.) of the fluid with a clean pipette, using a *dry* forefinger to adjust the volume. Transfer to a clean white dish or shallow cup. For acidities up to 0·3 per cent. (*i.e.* in Cheddar practice up to running the whey) take a second 10 ml. (or use a 20 ml. pipette). Add 2 ml. of 0·5 per cent. phenolphthalein solution, *i.e.* at the rate of 1 ml. for every 10 ml. milk or whey, and run in the alkali until within 0·5 ml. of the expected end-point. Thereafter add the soda drop by drop until the colour turns greyish. A few more drops are then usually sufficient to produce a very faint pink-orange colour which should be taken as the end-point. When in doubt, note the reading and add one drop more. Usually one drop equals 0·03 ml. When 20 ml. milk or whey are used, divide the reading by 20, instead of 10, unless the special acidimeter is used. If this procedure is adopted, not only will cheesemakers have a reading which is reliable and therefore of use, but results will be comparable from factory to factory. For acidities from press, 5 ml. whey may be used if desired, and in this case 0·5 ml. phenolphthalein should be added. It is, of course, advisable for one person to perform the titrations throughout for any one vat, but this is not always possible. This standard method will give acidity values about 0·02 per cent. "lactic acid" less than when using 3 drops of indicator solution, but the difference between the techniques is constant. (*See* Acidity, p. 9.)

***p*H measurements.** There is little doubt that, sooner or later, all factory manufacture will be standardised on *p*H measurements. This is not to imply that titratable acidities are of no use. It is important to bear in mind, however, that titratable acidity measures two things, of which one is the *p*H effect or true acidity effect, and the other the buffer or acid and alkali-absorbing capacity of the milk or whey. The latter is a measure of the protein and salts in the liquid.

$$\text{Titratable acidity} - - \begin{cases} \text{Lactic acid (producing a lowering of } p\text{H)} \\ + \\ \text{Protein and salts (resisting a lowering of } p\text{H)} \end{cases}$$

Perhaps the best description of *p*H for the cheesemaker is the "intensity of sourness" or true acidity. Thus if starter organisms produce, shall we say, 0·1 per cent. lactic acid in two milks or wheys of different initial acidities (*i.e.* richness in protein and salts) the milk or whey of higher initial acidity will be altered less in *p*H, as the high protein and salt content will have more alkali or acid-absorbing capacity than that of the poorer milk. A convenient analogy, which may help the practical person to appreciate the relationship of *p*H and titratable acidity, is that of temperature, calories, and specific heat, which may be considered analogous to *p*H, titratable acidity, and buffering capacity. Thus, just as adding so many calories of heat to any object will raise the temperature by an amount depending on its specific heat, so addition of a given amount of acid or alkali to a liquid such as milk or whey will lower or raise the *p*H by an amount depending on the buffering capacity of the liquid. So that :

$$\text{Temperature change} = \frac{\text{calories per gram}}{\text{specific heat}}$$

and

$$p\text{H change} = \frac{\text{ml. N acid (or alkali) per litre}}{\text{buffer value}}.$$

The buffer value of milk is about 20, *i.e.* to change the *p*H of milk by one unit (*e.g.* from 6·6 to 5·6) requires the addition of about 20 ml. N acid per litre. Since it is the *p*H which determines primarily the behaviour of the curd (*i.e.* the " body " aspects which are controlled by acid-base equilibrium and enzyme activity) it will be obvious that the *p*H changes are really of more fundamental importance to the cheesemaker than are the titratable acidities. Both together, however, give a much more comprehensive picture than either singly.

All factory cheesemakers should, as soon as possible, make *p*H *and* titratable acidity measurements as a routine procedure. A study of these values in the light of the behaviour of the cheese under different conditions and at different times of the year will be of the highest interest.

Methods of* pH *measurements. Electrometric methods, such as those with the glass or quinhydrone electrodes, are undoubtedly the best, and we believe that all factories will in time come to use them. However, few factories are at present willing to face the expense and trouble. Although the glass electrode is quicker and more convenient than the quinhydrone, it may be mentioned that the former normally requires about 20 ml. of whey, difficult to procure during " Cheddaring ", and that the quinhydrone can be used with the curd itself—an important advantage.

Moisture content of the curd. All cheesemakers and those interested in the scientific side of cheesemaking will agree that the moisture content of the curd at definite stages in the making process is, with the acidity, the most important of all factors controlling the finished product. It is highly probable that differences in these factors in making the different varieties of cheese are responsible for the different texture and body values and all related phenomena, and that these differences are dependent chiefly on the moisture content *and the way that this is held in the curd.*

Cheesemakers have long been searching for a simple method of estimating moisture content in curd. Some years ago the author showed that during the making process, as the moisture was driven from the curd, the specific gravity of the curd rose. This follows because the specific gravity of fat is 0·9, casein 1·6 and water 1·0. This increase in specific gravity could be followed by determining the behaviour of pieces of curd in brine solutions of different density. It is also possible to estimate moisture in curd by measuring either the volume of whey withdrawn or the weight of the curd. In the latter case, values for the total solids and density of the milk and whey have to be determined or assumed. Thus, if the curd is allowed to cool and drain on a miniature weighbridge, the loss in moisture can easily be followed.

The following formula permits the calculation of moisture in curd :

Per cent. moisture =

$$\frac{W_c - \left[\frac{T.S_m \times V_m}{10} - \frac{T.S_w}{10}\left(D_m \times V_m - \frac{W_c}{10}\right)\right]}{W_c} \times 100$$

Where :

W_c = weight of curd
V_m = volume of milk in gallons
D_m = density of milk (1·03)
$T.S_m$ = per cent. total solids of milk (12·8)
$T.S_w$ = per cent. total solids of whey (6·9)

The figures in brackets give values which have been assumed in calculating the examples below.

Table of Values. From 100 gal. of milk are obtained the following weights of curd or cheese during the making process :

	Moisture (%)
170 lb.	59·6
160 ,, ...	57·5
150 ,, ...	55·1
140 ,, ...	52·4
130 ,, ...	49·3
120 ,, ...	45·5
110 ,, ...	41·3
100 ,, ...	36·1

Absolutely accurate values are not obtained, as a number of assumptions have been made in devising this formula, but as a means of showing the *fall* in moisture it is of great value. As an indication of the range in cheesemaking the following values for Cannington Cheddar may be quoted :

	Moisture (%)
At pitching	50–60 (median 56)
On cooler	42–48
At milling	40–42

(Values by drying in oven.)

The "Pitching Point" of cheese (rheological aspects). One of the most important stages in the manufacture of many varieties of cheese is the pitching point. This is partly defined by a determination of acidity, but as every cheesemaker knows, the really significant factor is the consistency of the curd. The acidity test is used mainly as a convenient indirect measure of this. The consistency is judged by the expert by either or both of two methods : (*a*) moving the hand through the vat and judging the resistance of the individual floating particles of curd as they strike the hand ; and (*b*) taking a handful of curd out of the whey and squeezing.

That a skilled individual cheesemaker is able to reproduce his judgment of consistency by these methods is not only generally believed, but has been shown by quantitative experiments[1]; but it is also known that experts differ markedly from each other in their judgments, and that different factories under the same firm are liable to be working to very different standards. A measure of this consistency at the pitching point is clearly highly desirable, especially in time of war, when the uninterrupted services of a single individual can never be fully guaranteed. It has also been shown that the training of apprentices is greatly facilitated if they can be given a definite objective standard against which to measure their efforts in the process of learning a new technique.

During the scalding process there are many changes taking place in the nature of the curd. Of these the most important is the ever-increasing rigidity. Thus a cylinder cast from the curd will slump down under its own weight in the earlier stages of scalding, but will retain its shape well when the curd is ready to pitch. Also, the individual lumps of curd within the cylinder will retain whey and pack in together so that little or no whey can escape from the cylinder in the earlier stages, whereas later each lump keeps its characteristic shape and integrity, the whey pours out, being replaced by air, and the cylinder becomes an open-work structure with the lumps of curd in a comparatively open packing. This means that if we could cast a cylinder of curd of the same total weight each time during a series of tests while scalding proceeds and then measure the height of the cylinder after it has stood for a fixed time, the height of each sample would be greater than that of the previous one. It is not easy always to collect a sample of curd from the vat of exactly the same weight, but the same principle holds if we weigh the curd before casting and divide the weight by the measured height of the cast cylinder. This is a very simple test to carry out and takes only fifty sec., but in view of the continuous drain of whey it is most important that each stage in the process should be *accurately* timed. This can be done in three ways: (1) By means of a special clock which rings a bell after the appropriate number of seconds. (2) By having an assistant to call the times from the second hand of a watch. (3) With a little practice the person doing the test can keep one eye on a stop-watch and time the test himself. The performance of the test has been described by Scott Blair and Coppen and is as follows:

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[1] Scott Blair and Coppen (1940), *JDR*, **11**, 187.

Apparatus required. A wire gauze cylindrical basket about 2 in. high and 2 in. diameter (the sieve). Wire of mesh 16 per in. This is made to weigh 20 g. A disc of gauze fitted with suitable handle (the lid). A light xylonite disc preferably fitted with a small point of metal at the centre. A petri dish. A pointed steel rod (Meccano is convenient). This can be screwed down by means of a worm, so that the point rests on the metal point of the xylonite disc gently laid on the top of the sample. The position of the rod indicates the height of the sample. A 100-g. spring balance. To the pointer is soldered a false pointer arranged to indicate zero when the sieve hangs on the balance (*i.e.* 20 g. below the true pointer). This gives the weight of the curd without the sieve.

The test is performed as follows: The sieve is moved backwards and forwards near the bottom of the vat, stirring thoroughly, being finally raised to the surface full of curd. At this point the timing is started. Five seconds later the lid is placed gently on to the top of the curd in the sieve and the whole inverted, the sieve resting its full weight on the curd. It is important to see that the lid is in straight so as to form a cylinder of curd having parallel ends. Stray pieces of curd are gently removed from the outside of the sieve.

At fifteen seconds the sieve is again inverted, the lid removed, and the sieve hung on the spring balance (a basin or a second petri dish can be placed underneath to catch the whey). At twenty-seven seconds the weight of the curd is read and remembered. The sieve is taken off the balance, and the tin placed on top of the sieve, the sides of the tin being directed away from the sieve. At thirty-five seconds the sieve and tin are inverted, and placed, the tin (inverted), with the sieve on it, in the petri dish. The sieve is removed by sliding upwards, leaving the free cylinder of curd standing on the tin. The xylonite disc is lightly placed on to the cylinder of curd and the whole put under the pointed Meccano rod. This should be adjusted to read zero on the scale when there is no curd present. At fifty seconds the rod is screwed down so as just to make contact with the metal point on the xylonite disc, the height of the cylinder being recorded. The cylinder should not be " prodded " or touched at any time during the test. The " pitching " number is got by dividing the weight by the height.

The results. This method has been used satisfactorily for Cheddar, Cheshire, Leicester, Double Gloucester, Kingston, Caerphilly, Derby, and Dutch cheese, but the best pitching numbers have not yet been worked out for all these varieties. It is in any case possible to make very good cheese using quite unusual pitching numbers if the other stages of cheesemaking are suitably modified. The important thing is to know the pitching number which is wanted and to work to it. Reasonable variations to allow for any abnormal acidity of milk are of course necessary.

Tests for protein breakdown. The formol titration. This is a simple method of estimating free amino nitrogen in the milk and whey. Like the titratable acidity, it is not an accurate measure of anything in particular, but carried out under carefully standardised conditions it is capable of showing the extent of protein degeneration and especially of changes in the rate of protein breakdown.

Method. As soon as the ordinary titratable acidity test has been performed, add for every 10 ml. milk or whey 5 ml. of 50 per cent. commercial formalin (about 40 per cent. formaldehyde) neutralised with sodium hydroxide to a faint pink with phenolphthalein, and titrate again until the original end-point is reached. Values are conveniently expressed in terms of ml. N/9 NaOH per 10 ml. milk or whey.

Hot iron test. This test is held in great esteem by some cheesemakers, but is very crudely carried out. It is highly desirable that some standardised " iron " be designed and a simple device for ensuring that the temperature at which the test is carried out is within certain limits. Finally, we may mention that the test would be enhanced in value if the length of the threads were actually measured with a ruler, instead of being guessed, as they usually are.

Application of tests for changes in protein degradation. Rennet and acid together not only clot milk, but also change or slightly digest the casein, which process is at least partly responsible for the " mellowing " of the curd. In normal cheesemaking the increase in acidity (or fall in *p*H) and this change in the casein run parallel, but under abnormal conditions the rate of one in relation to the other may be altered. There is little doubt that the value of the hot iron test lies in the fact that the " ductility " of the curd depends not only on the *p*H but also on the extent of protein breakdown. As a simple method for studying this proteolysis, the formol titration of the whey has been investigated. Typical values for Cannington Cheddar are shown on the next page.

It must be realised that this titration is measuring the amino-nitrogen content of the whey which is controlled by two factors: (i) the rate of proteolysis as indicated by liberation of amino nitrogen; and (ii) the rate of loss of water by the curd.

	Ml. N/9 NaOH per 10 *ml.*			
Milk	1·45	1·45	—	—
Whey at cutting	0·5	0·5	0·7	0·65
,, at pitching	0·6	0·55	0·6	0·55
,, at drawing	0·6	0·6	0·6	0·7
,, at first turn	0·75	0·85	0·65	0·75
,, at milling	1·05	—	1·3	1·3
,, after salting	0·9	—	—	0·85
,, from press	1·1	1·0	0·95	1·25

Ripening of Cheese. *Chemical changes in ripening.* The chief chemical changes in ripening cheese, considered chronologically, are: (i) fermentation of lactose to lactic acids and small amounts of acetic and propionic acids and CO_2, (ii) proteolysis, and (iii) a slight fat breakdown. These changes are due to enzymes which may be derived from (*a*) the lactic acid bacteria (streptococci in the starter added, and lactobacilli later in the ripening cheese), (*b*) the miscellaneous bacteria in the milk, (*c*) the rennet used to clot the milk, and (*d*) the milk itself. A list of the enzymes is given in Table Ch X.

Sources of enzymes. (*a*) ***The lactic acid bacteria.*** The flora of a green (newly made) cheese is 99·9 per cent. lactic acid streptococci, the count reaching a peak of thousands of millions per g. These die out rapidly after about a month and are slowly replaced by lactobacilli. It is of interest to note that both the *Str. lactis* and *Str. cremoris* of the young cheese and the *L. casei* and *L. plantarum* of the maturing cheese are metabolically classified in Group I, *i.e.* they are the most poorly equipped with enzymes, both respiratory and fermentative. The distribution of types has been studied both at Reading and in New Zealand and an interesting difference has been noticed. Whereas English Cheddar develops mostly *L. casei*, New Zealand contains a greater proportion of *L. plantarum*. Whether this is responsible for the difference in flavour remains to be investigated. The reason for the difference also is a matter of speculation ; obvious possibilities are the use of pasteurised milk in New Zealand (the English investigations were made on raw milk cheese) and the higher proportion of fat in New Zealand cheese, the milk being derived from Channel Island cattle.

The lactic acid bacteria are probably the source of the volatile acid in young cheese, which is predominantly acetic. (*See also* Lactic acid bacteria.)

The proteolytic activity of the lactic acid bacteria is a more difficult matter to assess. Pure cultures produce variable amounts of non-protein nitrogen (NPN) in milk, more being found when chalk is present to neutralise the acid formed. Proteolysis is also enhanced when small amounts of rennet are present, this effect possibly being due to the slight breakdown of the casein affording a more assimilable medium for the bacteria. Lactic acid bacteria in cheese may produce up to 10 per cent. NPN in milk alone, and up to 35 per cent. in the presence of filtered sterile rennet, if the cultures are allowed to stand for 3 to 4 months at room temperature. It is generally assumed that the proteolytic enzymes of the lactic acid bacteria are only liberated on the autolysis of the dead cells—hence the slow breakdown of the protein.

A further aspect of this problem, which does not seem to have been considered by workers, is the possibility of the increases in the NP- and amino-N being due to the actual contents of the autolysed bacterial cells. It is impossible to determine the *total* bacterial count (*i.e.* all cells which have grown and died) of a cheese throughout its ripening, but, with an estimate of 10,000,000,000 per g. and assuming an average volume of 10^{-12} cm.^{3} for the bacterial cell, 80 per cent. as the moisture content, and 10 per cent. as the nitrogen in the dry weight, it is possible to calculate the nitrogen of the bacterial cells as 0·02 per cent. of the cheese, which contains about 4 per cent. total nitrogen and 1 per cent. NPN. It seems unlikely, therefore, that autolysed bacterial protoplasm is responsible for the peptones, etc., in cheese, but the material may play an important rôle in the flavour of the cheese. Sherwood has shown that desirable and undesirable flavours in cheese may be associated with specific *strains* of lactobacilli, the Group III (heterofermentive) types causing taints and other faults, whilst the desirable flavour is associated with intermediates (I-III) producing small amounts of by-products. It has further been suggested that slow growth is associated with the production of by-products, so that unfavourable conditions may change a typical Group I metabolism towards that of Group III.

(*b*) *Miscellaneous bacteria*. This term conveniently includes all types other than streptococci and lactobacilli. In good Cheddar cheese the proportion is usually below 1 per cent., *i.e.* cheese is a selective medium for streptococci and lactobacilli. Poor quality in cheese is associated with a higher proportion of other types, particularly coliforms and other gram-negative rods, and spore formers.

Milk coming into cheese factories varies enormously in hygienic quality, the count being from a few thousands to hundreds of millions. Many of these organisms are rich in proteolytic and lipolytic enzymes. It is not surprising, therefore, that cheese made from such milk ripens faster than that from clean milk. It also develops a fuller flavour and sometimes characteristic taints. The milk in many cheese factories is therefore pasteurised, and this destroys some 99·9 per cent. of the flora and usually prevents the faster ripening and the development of the fuller flavour and taints that would otherwise occur.

(*c*) *Rennet*. Rennet has two functions in cheesemaking : (i) clotting the milk, and (ii) breaking down the protein. Commercial rennet usually contains, in addition to rennin, small amounts of pepsin and other enzymes.

TABLE Ch X

ENZYMES IN CHEESE

Source	*Enzyme*	*Substrate*	*Products formed*	*Practical significance*
(1) Milk .	Lipase	Fat	Butyric caproic, etc, acids and condensation-oxidation compounds	Flavour (pungent)
	Proteinase (galactase)	Protein	Proteoses peptones, etc	?
(2) Rennet	Rennin	Casein complex	" Paracasein compounds "	Syneresis of coagulum–hardness of body
	Rennin papainase	Casein complex	Peptones etc	Mellowing of green cheese
	Rennin peptidase (?)	Casein complex	Peptides, etc	Mellowing of green cheese
	Pepsin and other enzymes	Protein	General proteolysis	Mellowing of green cheese (? bitterness)
(3) Lactic acid bacteria	Lactic acid system	Lactose	Lactic acid, etc	Flavour and syneresis
	Proteinases etc	Proteins	General proteolysis	Mellowing
(Streptococci)	Various	Lactose and lactic acid	Volatile acids alcohols, ketones, etc	Flavour in quick ripening cheese
(Lactobacilli)	Various	Lactic acid (and ? bound sugar in proteins)	Volatile acids, alcohols, ketones, esters, etc	Flavour in slow ripening cheese
(4) Miscellaneous bacteria	Proteinases	Protein	Peptones etc	General ripening and flavour May cause characteristic taints
	Lipases	Fat	Butyric etc acids	

Commercial rennet contains enzymes capable of at least four distinct actions: (i) clotting milk at *p*H 6·5 (rennin); (ii) proteolysis at *p*H 2 (pepsin); (iii) proteolysis at *p*H 4·6 (rennet papainase); (iv) proteolysis at *p*H 6 (peptidase).

This last peptidase is very variable in commercial rennet, so that it is possible that it is due to regurgitation from the duodenum or even of bacterial origin.

Many papers have been published on the rôle of rennet in cheesemaking, but it is not possible to assess it accurately on account of the difficulty of eliminating or controlling all other factors without disturbing the conditions obtaining in a maturing cheese. The rate of ripening increases with increasing amounts of rennet, but this fact does not necessarily imply a *direct* proteolytic action; the effect may be due to the rennet " preparing " the casein for the proteolytic enzymes of the lactic acid bacteria. Thus the combined action of sterile rennet + lactic acid bacteria produces a greater breakdown than the sum of the effects of each factor. If we assume that pepsin acts only on the positively charged protein (*i.e.* at *p*H $<$ 4·6) it will be evident that in Cheddar cheese (*p*H 4·9 to about 5·5) pepsin will have no effect unless at the iso-electric point an equal number of oppositely charged molecules exist, when it will be possible for a small fraction of the protein to be attacked by pepsin even at *p*H values $>$ 4·6.

The soluble protein found in the whey from rennet coagulation is probably the result of the first stages of the proteolysis.

The factors controlling the rate of clotting from a practical point of view are: (i) amount and strength of rennet, (ii) casein and calcium content, (iii) amount of soluble calcium, (iv) albumin and particularly globulin content, (v) season of the year (probably explicable by other factors), (vi) age of milk on testing (loss of CO_2 and change in protein and proteose fractions), (vii) temperature (optimum 41°—very slow below 20° C.), and (viii) *p*H. *See also* Enzymes and Rennet.

(*d*) *Milk* (*including enzymes added to milk*). Attention was paid to the possible rôle of the inherent enzymes of milk as factors in cheese ripening at an early date. The famous " galactase " once so fashionable is now rather discredited, as the early experiments were capable of other interpretation.

Many experiments have been made in which other proteolytic enzymes (trypsin, pepsin, and erepsin) have been added to cheese. Wojtkiewicz and Inikkoff found that trypsin markedly accelerated the protein breakdown and produced bitterness, but that pepsin and erepsin were without significant effect. Freeman and Dahle obtained the same results with trypsin and also found that the effects of added pepsin and rennin were small. Sherwood replaced rennin by pepsin and found that the proteolysis was less; increase of either enzyme led to increased proteolysis of the same general type.

Cheesemaking experiments with the addition of pancreatin, erepsin, and lipase have shown that while in some cases addition of pancreatin and erepsin improved the body and flavour, in most cases little effect could be observed, either by grading or by analysis. At one centre, pancreatin was considered to accelerate the ripening of the cheese and erepsin to have a retarding effect. The results obtained with lipase call for special consideration. The enzyme proved to be very powerful, and at a strength of 0·1 g. per gal. of milk produced a powerful " butyric ", rancid aroma by the time the curd was ready for milling. The smallest amount of enzyme used (0·025 g. per gal.) produced a characteristic, strong peppery aroma and sharp taste like very strong cheese, only more so. The graders in Somerset expressed great interest in this and described it as a " kexey " taint, long recognised but hitherto of unknown origin. The taint is associated with certain farms, and as occasionally cows are known to yield milk abnormally high in lipase – the milk becoming very rancid a short time after leaving the cow – it may reasonably be concluded that a local tendency to this taint is due to the presence in the herd of one or more cows yielding high lipase milk.

It is known that the higher volatile fatty acids increase as the cheese ripens and develops the characteristic pungent flavour of mature Cheddar. Pasteurisation largely destroys lipase, and cheese made from pasteurised milk is appreciably slower in developing characteristic cheese flavour. It would seem, therefore, that lipase is an important factor in controlling cheese flavour, whether from the milk itself or of bacterial origin, and that small amounts of lipase may well be of practical interest in the preparation of cheese from pasteurised milk

A list of the probable constituents of cheese flavour is given in Table Ch XI and a summary of factors affecting the ripening and flavour of cheese in Table Ch XII There can be little doubt that the chief changes in cheesemaking are

TABLE Ch XI

SUGGESTED CONSTITUTION OF FLAVOUR COMPLEX IN CHEESE

Flavour		*Substances responsible or possibly responsible*
Aroma	*Taste*	
	Acid	Chiefly lactic acid
" Lactic "		Lactic acid, etc
Butteriness		Diacetyl etc (? Esters)
" Cheddar "		(? Esters etc from protein fat and or lactate)
Sweet aromatic		Acetic and propionic acid compounds
" Cheesey "		(Butyric and valeric acid compounds)
Pungent	Hot	Caproic caprylic and capric acid compounds
	Bitterness	(' Peptones ') (? Tributyrin)

Brackets indicate that experimental evidence is inconclusive ' Cheddar ' flavour cannot be defined , many types of Cheddar exist

Notes (1) Pure fatty acids do not possess these flavours which only appear in aged acids (2) Flavour is considered to consist of aroma and taste Some graders do not taste cheese but this is to be deprecated as bitterness and other tastes escape detection (3) After tastes " are probably due to slowly soluble compounds

TABLE Ch XII

FACTORS AFFECTING RIPENING AND FLAVOUR

Factor	*Ripening (proteolysis)*	*Flavours*	
		Desirable	*Undesirable*
Time		+	+ ?
High temperature		0	+ + +
Humidity		—	+
Moisture			+ +
Salt	retards	?	retards
High *pH* (sweetness)			?
High bacteria	+	?	?
Extra rennet		+ (early)	(later)
Pepsin			?
Frepsin			+ ?
Trypsin (pancreatin)	+ +		+ ?
Lipase	—	?	+
Streptococci	+	some	
Lactobacilli I	+	+	
,, I III	+	+ + +	
,, III	+		+ +
,, II	+	?	?

enzymic, and that the palatability and digestibility of cheese are controlled by enzymic activity.

The following comments apply mainly to Cheddar cheese but not necessarily to other varieties. Factory methods are frequently modified to permit economies.

Treatment of Cheese. The care given to the cheese does not stop when the immature or " green " cheese is taken out of the press. Constant attention must be paid until the cheese is taken away by the buyer. The operations that must be performed may be summarised as follows: (i) bandaging; (ii) dressing; (iii) ripening, and if necessary (iv) storing, and (v) grading. The last two will depend upon the age of the cheese when sold. Some faults develop so late that examination at, say, three weeks does not reveal any blemish. Consequently the riper the cheese when the factor buys, the less chance of buying poor cheese and, of course, the sooner the sale to the consumer. Mature cheese, therefore, command higher prices. The time of selling is governed in addition by the law of supply and demand, and the maker will naturally keep his cheese if he believes that he will later obtain a higher price.

Bandaging. This takes place immediately after removal from press. The bandage may be retained by the maker when selling or it may remain on the cheese until it is received by the retailer. Bandaging has two main objects: general protection and the retention of shape. The larger the cheese the greater the force of internal distortion on the rind or surface and so the more important the rôle of the bandage. Cheddar cheese usually have a strong linen bandage laced on them in addition to the inner calico bandage, the former being retained by the maker. With Cheshire cheese the bandages are pasted on, and before despatch from the farm square cloths are placed over the top and bottom and tied together. Lancashire cheese have a thinner bandage sewn up above and below the edges being the softest of all the British " hard " varieties. Lancashire cheese are easily damaged during ripening, storage, and transport. With Gloucester, Derby, and Leicester cheese the caps and bandages are pasted on and no further covering is provided. Caerphilly cheese, although only " semi-hard ", do not require a supporting bandage on account of their shape, which is " flat and round ". Stiltons are purposely left unbandaged so that the surface may be scraped and treated during the period of formation of the coat. Being a semi-hard type and in the shape of a tall cylinder, these cheese easily become deformed. An easily detachable cloth is used to give support during the earliest stages of ripening.

Dressing. This term covers all external treatments of the cheese. These are extremely varied, especially with some continental varieties. The objects of such treatments are: (i) general protection, (ii) assistance in forming the coat or rind, (iii) improvement of appearance, (iv) prevention of loss of moisture and so reduction in weight, and (v) specific protection against external micro-organisms and insects.

The most common form of dressing is the application of oil, fat, or wax. For some types, powders such as flour, and cellophane or bladders, are used. Whatever the treatment the bandage is usually removed first; however, when varieties have thin bandages, such as the Lancashire, they may not be removed. Paraffin wax is used to a certain extent in Holland, Canada, and New Zealand, but although this has some advantages, the prejudice of the home market has prevented the general adoption of the practice.

If cheese are to be paraffined, a slight modification should be made in the method of manufacture, as " drying out " is largely prevented and the higher moisture content tends to permit the growth of fault-producing micro-organisms. A rather drier type of curd should, therefore, be produced. English cheese are not normally paraffined, but rubbed over with lard or butter. Caerphilly cheese are dusted with flour.

Dutch cheese are famous for their dressing; indeed, to the lay mind a Dutch cheese is a red cheese. Edam and sometimes Gouda are treated by washing in hot water, staining red with an aniline dye and then waxing.

Italian hard cheese are commonly treated with linseed oil, some varieties being first stained black. In some countries cheese made from skim-milk or incorporating a foreign fat must be coloured by law. The Italian Provoloni and some Dutch export cheese are encased in bladders, which, being transparent, are not readily recognised as such. Some foreign varieties such as Cacciocavallo are smoked before being treated with oil. Others are ripened in boxes packed with leaves, straw, or shavings, the object being in some cases to impart a characteristic flavour to the cheese.

Some varieties are packed in tinfoil or even allowed to ripen in tins. In the latter case the coat is first removed; a valve is essential to permit the escape of gas (carbon dioxide) produced by the bacteria in the cheese.

Care in the ripening room. As soon as the post-press treatment such as bandaging and dressing is completed, the cheese is removed to the ripening room. The space of this should be adjusted to cope with the largest possible number of cheese likely to be left on the hands of the maker. Although it is customary to have wooden shelves, wood saturated with whey is a good medium for the growth of moulds and other micro-organisms. Shelves should therefore be kept rigorously clean by washing with hot soda solution. The application of formalin or zinc chloride solution is usually effective in keeping down any tendency to mould growth. The most important factors controlling ripening are temperature and humidity. All cheese factories should therefore have means for controlling these two factors. Farmhouse makers usually trust to luck and therefore suffer in very hot and dry weather.

Temperature control. There are now many efficient automatic temperature control devices on the market. In summer at any rate the trouble is to prevent the temperature from rising; some form of refrigeration plant or cold water circulation is, therefore, essential. The best temperature to maintain is of necessity a compromise between that for the highest quality production and the economic necessities of market demand and available space. High temperatures accelerate ripening, but invariably lower the quality of the ripened product. Experiments have shown that quite low temperatures (*e.g.* 40° F.) produce cheese of higher grading (or score) than any higher temperature. The reason for this is that the temperature coefficient of the enzymes responsible for the ripening process is less than that of the growth of potential taint-producing organisms. In other words, ripening may proceed twice as fast, say, at 70° as at 40° F., whereas the potential taint-producing organisms which are always present, even in first-quality cheese, grow many times as fast at 70° as at 40° F. A belief that cheese ripened at very low temperatures develop bitterness has not been substantiated by recent experiments. From a quality point of view the following rules may serve as a guide to ripening temperatures:

Degrees Fahr.	
30–40	Ideal
40–55	Economically best
55–65	Inadvisable, especially for low-quality milk cheese
Over 65	Dangerous

For general purposes and considering all aspects, a temperature of 50° to 55° F. may be recommended. Some makers hold their cheese at a higher temperature for the first week or so to " get them going ", but this practice is to be deprecated.

The ripening temperature will naturally vary with the variety of cheese made, time of the year, and market requirements.

Humidity. High humidities lead to mould growth, " soft crowns ", and accelerated ripening; low humidities to cracking, shrinking, distortion of shape, and retardation of ripening in addition to excessive loss of weight. High humidities are avoided by ensuring efficient ventilation; low humidities, by having a vessel containing water placed in the ripening room or, for more drastic treatment, by hanging up wet cloths.

The correct humidity for ripening depends on the type of cheese. Soft cheese require a higher humidity (*e.g.* 95 per cent.) than open-textured hard cheese, and these again require greater humidities than close-textured cheese. Mould-ripened cheese such as Stilton and Camembert require higher humidities than non-mould ripened varieties. The rate of evaporation of moisture from any material will depend on: (i) temperature, (ii) humidity, (iii) surface exposed, (iv) affinity of the material for water, (v) velocity of air near the surface of the material.

The following figures may serve as a guide:

Type	*Approximate humidity* (%)
Soft cheese and mould-ripened cheese .	95
Open-textured and semi-hard cheese .	90
Close-textured and hard cheese . . .	85

In the British Isles the relative humidity is usually 80 to 90 per cent., which is thus suitable for Cheddar cheese.

Measurement of humidity. The most accurate method is that employing a wet-and-dry bulb thermometer. It is now possible to get a chart from which the humidity is read off directly, thus avoiding any calculation or looking up hygrometric tables.

A simple, cheap, and direct-reading instrument is the hair hygrometer. This is based on the principle that the length of a hair varies with the moisture absorbed by it, which in turn is controlled by the humidity of the air. Although appearing rather crude, good hair hygrometers are fairly reliable, although not as accurate as the wet-and-dry bulb thermometer.

Storage of Cheese. It is impossible to lay down any rules for the permissible time of storage of cheese varieties, as so much depends on the type, temperature, preferences of the market, and other factors. Thus some makers purposely concentrate on long-keeping varieties which, in the case of Cheddar, may be stored for a year or longer.

Storage is inevitably a continuation of the ripening processs, so that all the considerations applied to the ripening period apply equally to the storage period. Strictly speaking, the term *storage* applies to that period between the completion of the ripening process and the handing over of the cheese to the retailer. Actually we can never speak of the end of the ripening period as we can speak of the end, say, of the ripening of the milk in the cheese vat. There is no definite point at which a cheese becomes ripe and no definite point at which it becomes overripe. It is customary, however, to speak of the period during which the maker has charge of the cheese as the ripening period, and of that during which the factor has control, as the storage period.

A matter of practical importance is the loss in weight during storage, as a factor may buy a cheese weighing 80 lb. and find on selling it that it weighs, say, 77 lb. Early buying naturally increases the loss suffered by the factor, who adjusts his price accordingly. Some cheesemakers purposely make " wet " cheese in order to obtain a higher return, but usually lose more than they expect to gain on account of the low quality of product that they turn out. The rate of loss varies with: (i) type of cheese; (ii) age of cheese, decreasing with age; (iii) temperature of storage; and (iv) humidity of storage.

With ripe Cheddar the loss in store is about 1 per cent. per month.

Grading of Cheese. Grading is usually carried out by professional graders who are experienced makers and/or former instructors. The cheese is bored with a special type of borer (" iron ") which enables the grader to remove a cylindrical plug of cheese about 4 in. long and ½ in. in diameter and to replace it without doing the cheese any serious damage. Borers of specially hardened steel give the best plug but always give off a characteristic smell. Stainless steel borers are free from this drawback but do not bore so cleanly.

Technique of grading. A note of the general appearance of the cheese (coat, bandaging, and dressing) is made and then a plug drawn, examined for colour, smelled, and then a piece " rubbed down " between thumb and finger. This converts the cheese to a soft waxy consistency and the heat of the grader's hand intensifies the aroma. Some graders do not taste the cheese, but this is really a serious omission as it is possible to get a cheese which, although satisfactory to the smell, has a definite off-flavour detectable only by taste. Such a fault may not be detectable until a few seconds after the beginning of mastication—the so-called after-taste. An attempt is made to identify taints by names, which are sometimes so vague that the grader himself is unable to describe what he means.

The following terms are commonly used :

Description	*Cause*
Acid, sour or sharp	Too much acid (various causes)
Bitter	Too acid, or specific micro-organisms
Fruity (often a specific fruit can be named)	Yeasts—rarely bacteria
Tallowy	Fat decomposition
Flat, insipid	Lack of cheese flavour
Off-taint (non-specific)	Chemical action by fault-causing micro-organisms

Body. Although many graders confuse body and texture, or at any rate do not assess them separately, they should be considered individually.

Body has two aspects or components : (i) hardness or resistance to pressure, and (ii) smoothness or feeling to the tongue. The latter is not yet capable of scientific measurement, but the former has been interpreted in terms of scientific characteristics and can be analysed and measured.

The grader usually indicates *firmness* as :

(1) Very soft	Increasing hardness
(2) Soft	
(3) Rather soft	
(4) Normal	
(5) Firm, or	
(6) Overfirm	

And smoothness as :

(1) Silky	Increasing roughness
(2) Chalky, or	
(3) Gritty	

Texture. This may be defined as the appearance to the eye, excluding colour. In practice it is confined to an estimate of " openness " or how closely the curd is knit together. " Open texture " may be due to the development of fairly large cracks or to general lack of knitting together of the curd detectable by closer inspection. A " short " texture indicates not only openness but brittleness.

Colour. The terms usually used are : (i) pale, (ii) normal, (iii) deep, (iv) mottled, and (v) muddy. In addition there are other specific colour faults due to micro-organisms.

The colour of cheese (or any other dairy product) may be measured with the Lovibond tintometer. Quite specific local preferences for a particular colour exist, and cheese are accordingly coloured with annatto. It is not uncommon to find a demand for a coloured cheese in one district, while that in an adjoining *district is for an uncoloured. The public pays far too much attention to colour,* as witness for example the request for a " red cheese ", as if annatto conferred a particular flavour or characteristic to the cheese. It is possible that in cheese, as in other foods, colour conveys a " flavour impression ".

During the war the entire control of manufacture, grading, and distribution was taken over by the Ministry of Food. Official graders stamp the cheese as first, second, third, or no grade, and the use of colour has been discontinued.

Yield of Cheese. For milk of F per cent. fat content and C per cent. casein, yield of green cheese per 100 lb. of milk is : (i) $1{\cdot}63\,(C + F)$ (van Slyke and Price) ; Prices; (ii) $1{\cdot}40\,(C + F) + 1{\cdot}04$ (van Slyke) ; (iii) $1{\cdot}22\,(C + F) + 2{\cdot}32$ (McDowall).

See Abnormal milk ; Annatto ; Fatty acids ; Flavours ; Grading; Lactic acid bacteria ; Management of Creameries; Mastitis; Pasteurisation, p. 824; Prices; Refrigeration; Rennet; Rheology; Stability; World production.

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10, 118 (white particles in mature cheese); McDowall and Whelan (1938), *JDR*, **9,** 339 (solubility of curd in brine); Mattick (ECV) (1938), *JDR*, **9,** 233 (calcium and phosphorus in cheese); Ling (1937), *JDR*, **8,** 173 and (1936), **7,** 145 (calcium and phosphorus in whey); Davis *et al.* (1937), *JDR*, **8,** 238 (rennet and lactic acid bacteria in proteolysis); Barnicoat (1937), *JDR*, **8,** 53 (effect of metallic contaminants); Dolby *et al.* (1937), **8,** 74 and 86 (acidity and mineral content); Davies *et al.* (1937), *JDR*, **8,** 92 (effect of chemicals on ripening); Sherwood (1936), *JDR*, **7,** 271 (cheese from raw and pasteurised milk); McDowall and Dolby (1936), *JDR*, **7,** 156 (chemical changes and bound water).

CHEESE FLY. This is a small black fly which lays eggs in the cracks of cheese. The eggs hatch out in about three days to give "jumpers" which become flies in three to four weeks.

CHEESE MITE. This is a member of the genus *Arachnidae*. It owes its survival to the high resistance of the egg to unfavourable factors. The larvae emerge in from ten to twelve days. The commoner species of mite infesting cheese are *Tyrolichus casei* and *Tyrophagus longior* (Solomon 1943). Although these mites are usually less than a millimetre long when fully grown, they undoubtedly cause serious damage to cheese, their presence sooner or later being indicated by the characteristic dust-like debris on shelves and surfaces of the infested cheeses (Robertson, 1948). Various methods have been considered for their control, including the use of dusts and fumigants (Muggeridge and Dolby, 1946). In their useful paper on the subject, Muggeridge and Dolby concluded that dusts were not effective for controlling cheese mite infestation but useful control could be achieved by fumigation with either methyl bromide or dichloroethyl ether. The use of methyl bromide, however, requires special precautions on account of its toxicity to man and, to be effective, fumigation must be carried out in a specially sealed room or fumigation chamber. Dichloroethyl ether is also toxic to man, but its lachrymatory properties would serve as a useful warning to operators exposed to undesirably high concentrations. Dichloroethyl ether can be applied as a fumigant and also sprayed directly on to infested shelves, etc. (*See* Muggeridge and Dolby for practical details.) Provided the exposed cheese were thoroughly aired following treatment (about a fortnight) no taint due to the fumigant could be detected even in the exteriors of the cheese. The experiments of Muggeridge and Dolby suggest that there would be little danger of methyl bromide residues persisting in fumigated cheese. Absorption of methyl bromide during fumigation rapidly reached equilibrium and was therefore likely to be purely physical, in which case complete desorption would be expected on airing. Gammexane dusts applied to the surfaces of infested cheese and the use of smoke generators in store rooms, etc., have also been considered for the control of mite infestations. The use of this and similar oil-soluble, non-volatile insecticides must be viewed with considerable caution until more data are available on the magnitude, persistence, and possible toxicity of the residues in cheese. *See* Insecticides.

Refs.: Muggeridge, J. and Dolby, R. M. (1946), *N.Z. J. Sci. Tech.*, **28,** 1–30 (Control measures); Robertson, P. L. (1948), *N.Z. J. Agr.*, **76,** 385 (Damage); Robertson (1952), *JSDT*, **5,** 86; Solomon, M. E. (1943), "Tyroglyphid mites in stored products" H.M.S.O. (Ecology, etc.).

CHEESINESS IN BUTTER. A characteristic flavour, produced by certain bacteria capable of causing butyric and allied fermentations. *See* Cheese; Flavours.

CHEMICAL REACTIONS. A chemical change or reaction may be defined as one in which the arrangement of the atoms *inside the molecule* is permanently altered to give a new substance. Instead of one or more substances with their individual properties, *e.g.* colour, odour, density, melting point, etc., we obtain, after a chemical change, one or more new substances with different properties which do not revert automatically to the previous substances. Examples of chemical changes are

$$\underset{\text{hydrochloric acid}}{\mathrm{HCl}} + \underset{\text{sodium hydroxide}}{\mathrm{NaOH}} \rightarrow \underset{\text{common salt}}{\mathrm{NaCl}} + \underset{\text{water}}{\mathrm{H_2O}}$$

$$\underset{\text{starch}}{(\mathrm{C_6H_{10}O_5})_n} \xrightarrow[\substack{\mathrm{H_2O} \\ \text{enzymes}}]{\text{acids}} \underset{\text{sugar}}{\mathrm{C_6H_{12}O_6}}$$

The change of water to steam or ice is not a chemical change because, although new substances are formed, they can revert to the original substance. All three substances consist of water in various degrees of condensation or association of the molecules $(H_2O)_n$ but in each the molecule of water H_2O retains its individuality—two atoms of hydrogen are always combined in the same way with one atom of oxygen. The disruption of the molecule to form hydrogen and oxygen is a chemical change and the mixture of hydrogen and oxygen does not automatically become water again.

Types of chemical reactions

(1) *Disruptive*

$$\underset{\text{lactose}}{\mathrm{C_{12}H_{22}O_{11}}} \xrightarrow[\substack{\text{enzymes} \\ \mathrm{H_2O} + \mathrm{O_2}}]{\text{bacterial}} \underset{\text{lactic acid}}{\mathrm{2C_3H_6O_3}} + \underset{\text{acetic acid}}{\mathrm{2C_2H_4O_2}} + \underset{\text{carbon dioxide}}{\mathrm{2CO_2}}$$

(2) *Additive or condensation*

$$\underset{\text{iron}}{\mathrm{3Fe}} + \underset{\text{oxygen}}{\mathrm{2O_2}} \rightarrow \underset{\text{iron oxide (rust)}}{\mathrm{Fe_3O_4}}$$

(3) *Exchange*

$$\underset{\text{washing soda}}{\mathrm{Na_2CO_3}} + \underset{\text{slaked lime}}{\mathrm{Ca(OH)_2}} \rightarrow \underset{\text{chalk}}{\mathrm{CaCO_3}} + \underset{\text{sodium hydroxide}}{\mathrm{2NaOH}}$$

(4) *Isomeric change*

$$\underset{\text{ammonium cyanate}}{\mathrm{NH_4CNO}} \rightarrow \underset{\text{urea}}{\mathrm{CO(NH_2)_2}}$$

(5) *Polymerisation*

$$\underset{\text{ethylene}}{\mathrm{C_2H_4}} \rightarrow \underset{\text{polythene}}{(\mathrm{C_2H_4})_n}$$

(6) *Depolymerisation*

$$\underset{\text{nitrogen tetroxide}}{\mathrm{N_2O_4}} \rightarrow \underset{\text{nitrogen dioxide}}{\mathrm{2NO_2}}$$

CHEMICALS, COMMON NAMES OF.

Alum . . .	Potassium aluminium sulphate, $K_2SO_4 . Al_2(SO_4)_3 . 24 H_2O$
Aqua fortis . .	Nitric acid, HNO_3
Aqua regia . .	Nitric + hydrochloric acids
Blue vitriol . .	Copper sulphate, $CuSO_4 . 5H_2O$
Carbolic acid . .	Phenol, $C_6H_5 . OH$
Caustic potash .	Potassium hydroxide, KOH
Caustic soda . .	Sodium hydroxide, $NaOH$
Chalk . . .	Calcium carbonate, $CaCO_3$
Common salt . .	Sodium chloride, $NaCl$
Copperas . .	Ferrous sulphate, $FeSO_4 . 7H_2O$
Corrosive sublimate	Mercuric chloride, $HgCl_2$
Epsom salts . .	Magnesium sulphate, $MgSO_4 . 7H_2O$
Glauber's salt . .	Sodium sulphate, $Na_2SO_4 . 7H_2O$
Grape sugar . .	Glucose or dextrose, $C_6H_{12}O_6$
Green vitriol . .	Ferrous sulphate, $FeSO_4 . 7H_2O$
Iron alum . .	Potassium ferric sulphate $K_2SO_4 . Fe_2(SO_4)_3 . 24H_2O$
Lime . . .	Calcium oxide, CaO
Lunar caustic .	Silver nitrate, $AgNO_3$
Muriate of lime .	Calcium chloride, $CaCl_2$ (as used in " brine ")

Oil of vitriol	Sulphuric acid, H_2SO_4
Potash	Potassium hydroxide, KOH
Plaster of Paris	Calcium sulphate, $CaSO_4$
Red lead	Triplumbic tetroxide, Pb_3O_4
Rust (iron)	Iron oxide, Fe_3O_4
Salammoniac	Ammonium chloride, NH_4Cl (as used in wet Leclanché cells)
Slaked lime	Calcium hydroxide, $Ca(OH)_2$
Soda	Sodium hydroxide, NaOH or sodium carbonate, Na_2CO_3
Spirits of salts	Hydrochloric acid, HCl
Sugar of lead	Lead acetate, $Pb(C_2H_3O_2)_2$
Verdigris	Basic copper acetate
Vinegar	Impure dilute acetic acid
Washing soda	Sodium carbonate, $Na_2CO_3 . 10H_2O$

CHEMICALS IN DAIRY PRODUCTS. *See* Flavours; Metals; Preservatives.

Refs.: Richmond; Tollenaar and Mossel (1953), *IDC*, **3**, 1381.

CHEMICAL STERILISATION. Certain chemicals are suitable for sterilising metal utensils, water, etc. They are particularly useful where other methods such as heat, steam, etc., cannot be employed.

The advantages are: (i) convenience; (ii) cheapness; (iii) speed.

The disadvantages are: (i) smell; (ii) corrosion; (iii) legal objections.

Of all those ever tried, chlorine in the form of solutions of hypochlorites, or chloramine, or electrolytically produced, is by far the best.

In the dairy industry chlorine is specially useful for (i) cows' udders which cannot be treated by physical means; (ii) vats, tankers, etc., which cannot conveniently and quickly be sterilised by steam or hot water; (iii) air, by spraying; (iv) water used for washing and rinsing, especially in bottle-washing machines. *See* Chlorine, Cleaning and Sterilising; Detergents; Disinfection; Sterilisation.

Refs.: McCulloch; Resuggan.

CHEMISTRY, DAIRY. The advances in this subject have been described in the following reviews:

Aschaffenburg and Rowland (1952), *JDR*, **19**, 226; Aschaffenburg, Rook and Scott Blair (1949), *JDR*, **16**, 390; Rowland and Scott Blair (1942), *JDR*, **13**, 93; (1940), *JDR*, **11**, 84; Davies (1938), *JDR*, **9**, 95; (1936), *JDR*, **7**, 75; (1934), *JDR*, **5**, 75.

The following are the chief text-books:

Davies; Ling; Richmond; Rogers; Tyler.

CHESHIRE. *See* Cheese, p. 187.

"CHESSITS." *See* Cheese, p. 191.

CHILE.

Ref.: Dalgalarrando and Cornejo (1949), *IDC*, **5**, 151.

CHILLED WATER. This is used in place of brine for cooling in some dairies. Its advantages are: (i) cheapness; (ii) absence of corrosion in plant; (iii) no effect on floors, etc.; (iv) no risk of freezing milk in plant as it is used at 32° to 35° F.; (v) greater thermal capacity; (vi) no chemical control is required. More chilled water than brine is required in practice as its temperature is higher. If 4 gal. of brine are required for 1 gal. milk, then about 6 gal. of chilled water will be required. With certain types of equipment efficient thermostatic control is essential to prevent freezing of the water. *See* Brine; Cooling; Refrigeration

Refs.: Davis (1952), *F*, **21**, 467; Milligan (1950), *JSDT*, **4**, 30.

CHLORIDE CONTENT OF MILK. Normal milk contains about 0·07 per cent. chloride (Cl), and this component controls the osmotic pressure and so the freezing-point of the milk. If for any reason, *e.g.* mastitis, the lactose falls in concentration, the chloride rises to maintain the osmotic pressure. The *Koestler number* is $\frac{\text{per cent. chloride} \times 100}{\text{per cent. lactose}}$, and is usually less than 2 for normal, and above 3 for abnormal milk. Broadly speaking, the limits for normal milk chloride are

0·05 to 0·12 per cent. Abnormal milks may go as high as 0·30 or even higher, but such samples are usually from cases of clinical mastitis. Heifers give milk of low chloride content, and not only mastitis, but stage of lactation, age, feed, etc., can increase the chloride content.

Quick methods for chloride based on conductivity may be used for detecting mastitis, but it is essential to diagnose abnormalities by differences between quarters and not by absolute values. *See* Abnormal milk ; Mastitis ; Rapid abnormality indicator.

Refs. *Milk Testing ;* Richmond ; Davies.

CHLORIDE-LACTOSE RATIO. The chloride and lactose in milk account for about 75 per cent. of the total osmotic pressure and various formulae have been suggested to relate the two. The following table summarises these :

Author	*Formula*
Kopatschek	44(lactose + chloride) = constant
Koestler	$\frac{100 \times \text{chlorine}}{\text{lactose}}$ = Koestler no. $= < 2$ for normal milk $= > 3$ for abnormal milk (*q.v.*)
Mathieu and Ferré	Lactose + lactose equivalent of chloride (in g. per litre) = at least 70. (If the value of this "simplified molecular constant" falls below 70, adulteration with water is suspected. A simpler formula is per cent. lactose + 19·6 per cent. chloride = 7.
Sundberg	Lactose = 7·07 − 18 chloride (percentages)
Davies	Lactose = 6·26 − 13·5 chloride (percentages)

CHLORIDE OF LIME. *See* Bleaching powder.

CHLORINE, AVAILABLE. The important property of a hypochlorite preparation or of bleaching powder is its available chlorine, *i.e.* how much is available to act as an oxidising agent. For estimating very small amounts (0 to 1 p.p.m.) the *o*-tolidine method should be used ; for larger amounts (5 to 250 p.p.m.) the Tintometer disc based on displacement of iodine from iodide by chlorine may be used. For accurate estimations the arsenite titration method should be used.

Concentrated commercial preparations usually contain about 100,000 p.p.m. *See* Hypochlorites ; Water.

Ref.: LCDP.

CHLORINE FOR STERILISING WATER SUPPLIES. The water problem is perhaps the most serious problem on many dairy farms and it does not seem to be generally known that a water supply can be made satisfactory under emergency conditions by the addition of chlorine. If quite clear and colourless from 2 to 5 p.p.m. (1 to 2 teaspoonfuls in 10 gal.) should be added at least one hour before use ; if turbid or brownish 10 p.p.m. (1 teaspoonful to 1 gal.) should be used. The ordinary chlorine (hypochlorite) disinfectants at full strength contain about 10 per cent. available chlorine, *i.e.* 100,000 p.p.m. To add 10 p.p.m., therefore, 1 lb. ($\frac{1}{10}$ gal. or nearly 1 pint) should be added to 1000 gal. water. For use in the cowshed, the direction given by the makers should be followed ; it is a common fault to use chlorine preparations that are too strong, and this should be avoided as it may lead to rough, dry skin not only on the cows' teats but on the milkers' hands.

Harrison and Mattick (1941), *SAB*, p. 41, recommend the following routine :

Cow washing. Enough hypochlorite to give a concentration of 800 p.p.m. available chlorine should be added to 2 gal. water in pails. This is enough for about twelve cows.

Two buckets must be used, one containing two cloths for washing down the animals, the cloths being used alternately. (The one not in use is left in the disinfectant water.) The other bucket should contain two cloths for wiping, these also being used alternately.

Teat cups. Two gal. of water containing hypochlorite (800 p.p.m. available chlorine) for twenty-four teat cup clusters.

After milking a cow and before starting to milk another:

(*a*) Rinse the teat cup cluster in a bucket of clean cold water by vigorously plunging mouths of teat cups downwards, four times in five sec. The vacuum must be off. (This water must be changed *after every two teat cup clusters.*) (*b*) Drain for 5 sec. (*c*) Dip into a 2-gal. bucket of water containing hypochlorite, plunging, as above, three times in 4 sec. (*d*) Drain, shaking the cluster, for 3 sec.

Hand washing. Use 2 gal. of water containing hypochlorite (800 p.p.m. available chlorine).

After washing in soap and water the hands must be rinsed *before* and *after* handling each cow, when using the strip cup prior to milking and between strippings.

Modern Chlorination Practice. A notable advance in water purification practice has been made with the introduction of break-point chlorination—chlorination to the establishment of free available chlorine residual which is at least twenty to thirty times more efficient as a bactericidal agent than the combined available chlorine normally resulting from the application of minimal dosages. In break-point chlorination the treatment is extended to permit the free oxidation potential of the chlorine to take effect, and the oxidisable matter destroyed includes ammonia and amino compounds upon which bacteria feed, taste-forming bodies such as algae spores and phenolic compounds, iron salts and colloidal material.

As chlorine is added to a water it will be found that the chlorine residual will increase. During this application we get the typical tastes and odours commonly associated with chlorinated water (Fig. W 9). Then, as additional chlorine is added, the chlorine residual decreases through the chemical reaction of the chlorine and substances known as chloramines. By the addition of more chlorine beyond this point, however, the residual will then rise, usually in direct proportion to the rate of applied chlorine. This is the break-point in the chlorine residual curve. Examination of the water at a point of dosage following this break-point will show that the intensified tastes and odours previously found have been eliminated or considerably reduced. As the rate of chlorination is increased the tastes become chlorinous in nature due to the establishment of free available chlorine residuals. An exemplified explanation is as follows:

With the addition of chlorine to water, it is not possible to recover the total amount of measurable chlorine residuals, as chlorine first reacts with various reducing substances such as hydrogen sulphide and other organic materials which may be in the water. The amount which reacts is responsible for the initial chlorine demand. Over this amount excess chlorine will react with any ammonia present to form chloramines and with further addition of excess chlorine, chloramine is destroyed in proportion to the amount added. When an equivalent amount of chlorine is added to the maximum amount of chloramines that can be formed they react with each other in their complete destruction resulting in zero chlorine.

The practice of break-point chlorination in process waters has led to a considerable decrease in bacterial counts as well as prevention or inhibition of slime Results have shown that control of bacterial contamination can be maintained. The break-point chlorination process should not be regarded merely as a sterilising system but as a method for all-round chlorinating quality. It should be remembered, however, that every plant with its varying water characteristics presents a separate and distinct problem and the planning of an installation of this nature should be given proper consideration with the aid of competent personnel. *See* Cleaning and sterilisation of plant; Detergents; Disinfectants; Hypochlorites; Water.

Refs.: LCDP; McCulloch; Clegg and Cuthbert (1951), *SAB*, **14**, 200 (farm chlorinator); Whitlock (1954), *PSWTE*, (in press) (chlorine activation of silica): Allen and Brooks (1952), *SAB*, **15**, 155; Neave and Hoy (1947), *JDR*, **15**, 24 (Cl disinfection of metal surfaces); Wolf *et al.* (1946), *JDR*, **14**, 291 (Cl mists against phages); Cousins and Wolf (1946), *SAB*, p. 15 (effect of pH on Cl sterilisation); Wolf and Batchelor (1946), *SAB*, p. 59 (critical humidity in Cl disinfection); Cousins (1946), *SAB*, p. 77 (humidity in Cl aerosol disinfection); Wolf and Brown (1946), *SAB*, p. 99 (germicidal power of mouth-washes); Bowyer *et al.* (1945), *SAB*, p. 57 (steam and Cl for utensils).

CHLOROFORM. Milk can be preserved for some time by the addition of 1 per cent. chloroform. Enzyme action is not stopped. *See* Phosphatase test.

CHLORPHENOL TAINT. It is well known that chlorine in water can sometimes be detected more easily when tea is made with it than by drinking the water alone. This is because the chlorine combines with the phenolic substances in the tea to produce the highly odoriferous *chlorphenols*. Similarly if very minute amounts of phenol (or carbolic acid) and chlorine are added to milk it is possible to detect both substances together when neither would be detected alone. It is claimed that 1 part in 100,000,000 can be detected in this way. Thus, one way to test milk for chlorine is to add a trace of phenol, *e.g.* ten parts per million, and vice versa.

CHOCOLATE MILK. These popular and nutritious drinks consist of a mixture of whole or skimmed milk, cocoa, and sugar together with (usually) flavouring agents and a stabiliser. The common stabilisers are soluble starch, agar, alginates, carrageen or Irish moss, gelatine, etc. Without a stabiliser the cocoa settles on the bottom and experience suggests that Irish moss, glyceryl monostearate, and trisodium phosphate form the most suitable mixture.

The use of skim milk gives naturally a harsher product than whole, but high fat milks tend to give cream layer troubles and for this reason a fat content of just over 2 per cent. appears to be most popular. Homogenisation avoids this trouble. High pasteurisation temperatures or sterilisation also minimise the rising of the cream. The best treatment appears to be 165° to 180° F. for 30 min. The hot milk should be agitated continuously and cooled over a surface cooler. The homogenisation pressures vary according to the procedure, 1000 to 1500 lb. if all ingredients except stabiliser are present in the mixture, and 2500 to 3000 lb. if a stabiliser is present. The sterilising temperature varies according to a number of factors; the final product should be filled preferably hot but, if not, then cold.

Refs.: Speck and Lucas (1951), *JDS*, **34**, 333 (*HTST* past.); Reid (1946), *MPM*, **35**, No. 10, 72 (food values); (1944), *MD*, **34**, No. 1, 47 (costings); Hadary (1944), *MD*, **33**, No. 9, 30 (consumption); Meuller, Fuller and Swanson (1942), *JDS*, **25**, 883 (bacteriology); Brereton, Combs and Macy (1940), *MD*, **29**, No. 5, 38 (physical aspects); Smallfield (1937), *CDIC*, **16**, No. 8, 53 (preparation).

CHOLESTEROL. This complex aromatic alcohol $C_{27}H_{45}OH$ occurs in milk to the extent of about 0·07 per cent. It is insoluble in water and so is associated with the fat in milk. Separator slime, however, is claimed to contain 4·5 per cent. cholesterol.

A similar substance *phytosterol* occurs in vegetable fats and the identification of phytosterol acetate by its melting point can be used to detect addition of vegetable fats to dairy products.

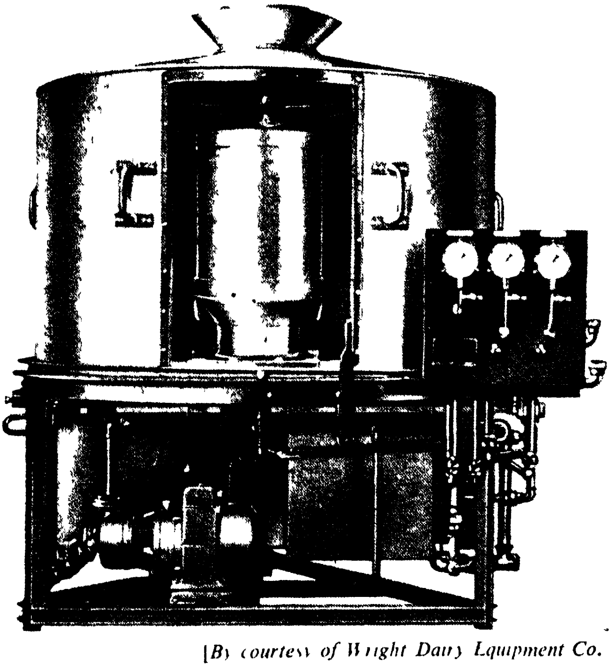
Chemically cholesterol is closely related to ergosterol and vitamin D (p. 1056).

CHROMATOGRAPHIC ADSORPTION ANALYSIS. The separation of chemical substances, especially coloured ones, by passing a solution of them through a column of a white adsorbent powder such as chalk or alumina or through paper strips.

Refs.: Zechmeister (1950), *Progress in Chromatography*; Williams (1946), *Introduction to Chromatography*, London; Zeichmeister and Cholnoky (1941), *Principles and Practice of Chromatography*, London; Strain (1945), *Chromatographic Adsorption Analysis*, New York; Woiwood (1949), *JGM*, **3**, 312 (bacterial cultures); Proom and Woiwood, 319 (N metabolism).

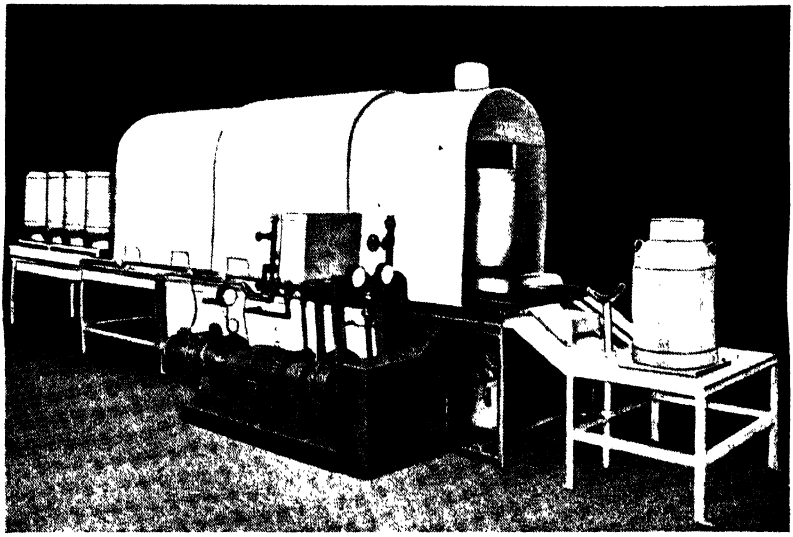
[By courtesy of the Milk Marketing Board

FIG. Ch 8 — *A Cheddar Cheese Store Room*



[By courtesy of Wright Dairy Equipment Co.

FIG. Cu 1. –*Rotary Churn Washer.*



[By courtesy of U.D. Engineering Co. Ltd.

FIG. Cu 3.—" *UDEC" Straight-through Can Washer.*

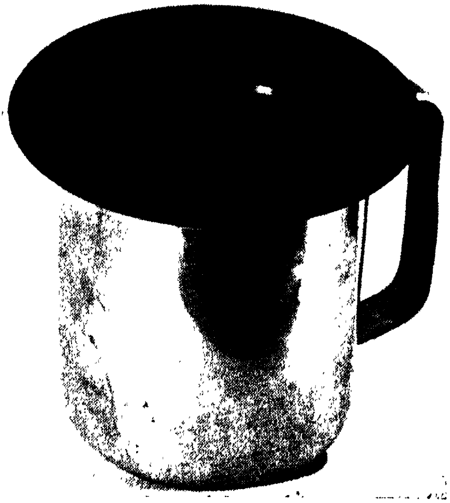
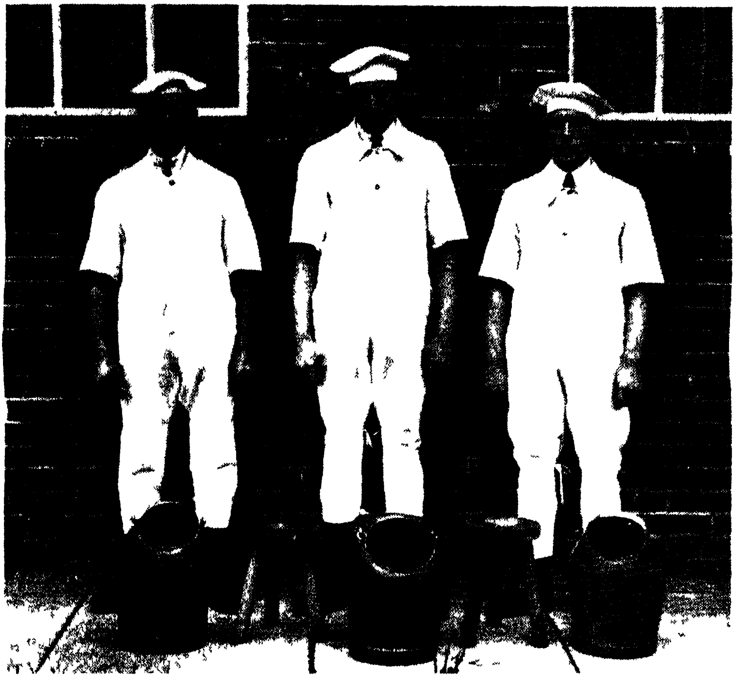
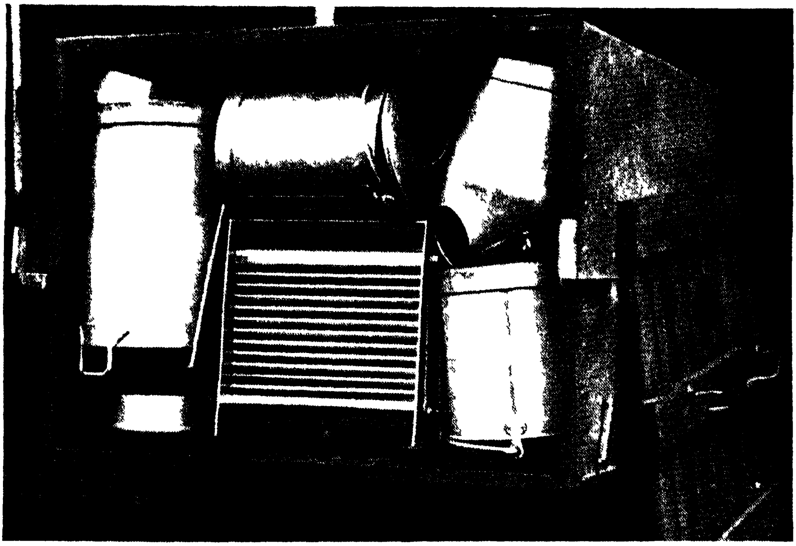


FIG. Cc 1.— *Strip Cup. White Clots in the Milk Show up against the Black Background.*



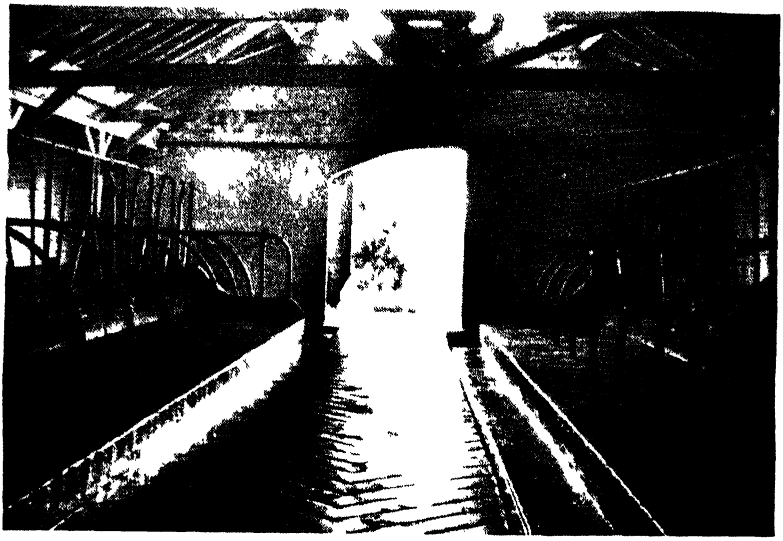
[*By courtesy of N I R D*

FIG. Ce 2 —*Milkers in Clean Caps and Overalls with Washed Hands, Sterilised Pails, and Washed Stools*



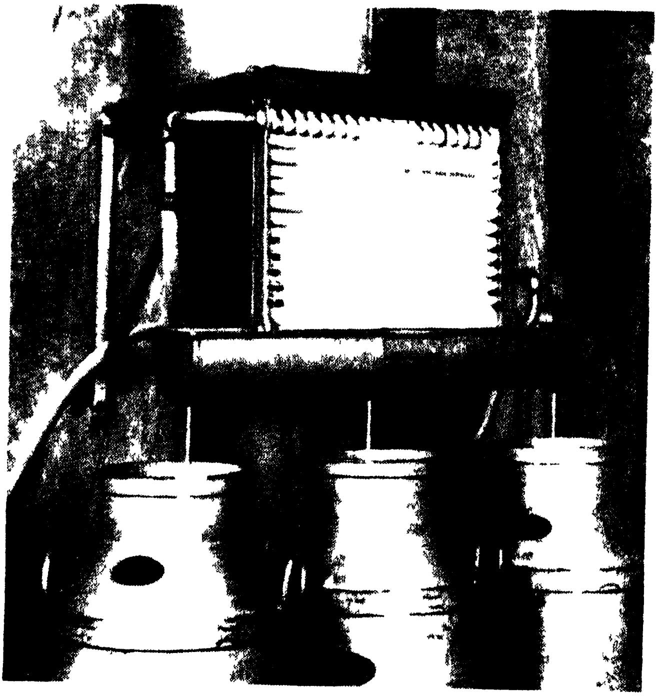
[*By courtesy of N I R D*

FIG. Ce 3 —*Steam Sterilising Chest with Pails, Churn, Cooler, and Plunger ready for Sterilising. Note that Utensils are Inverted or Sideways to Prevent Air Lock. Air is Heavier than Steam.*



[*By courtesy of N I R D*

FIG. Ce 4.—*Milking Shed with Raised Standings, Gutters, Concrete Floors with Fall, and Plenty of Space. Note absence of Dung, Feeding Stuffs, and other Sources of Dust. Floors are Wet.*



[*By courtesy of N I R D*

FIG. Ce 5.—*Milk being Cooled over Surface or Capillary Type Cooler. Note Even Flow of Milk and Distribution into Three Churns to Equalise Fat Content.*

CHROMIC ACID SOLUTION FOR CLEANING GLASSWARE. Add 200 ml. hot water to about 90 g. potassium (or sodium) bichromate, stir to dissolve, cool and add carefully 2 litres of commercial (95 per cent.) sulphuric acid. Stir to dissolve the precipitate. The solution may be kept in a glass cylinder or conical flask (filter type), and should be discarded when green.

CHROMIUM. Chromium plated steel is corrosion-resistant for dairy purposes, but peels sooner or later. It is therefore inferior to the stainless steels (p. 689). *See* Metals.

CHROMOBACTERIUM. A genus of small, aerobic, non-spore-forming, Gram-negative rods forming a pigment which may be violet, red, or yellow (English classification) or violet (American (Bergey) system). Type species is *Chr. violaceum*. *See* Classification.

Refs.: Bergey ; Wilson and Miles.

CHROMOGENESIS. Colour production by micro-organisms. *See* Butter; Cheese; Classification; Colour faults; Stability.

CHURNING. The violent agitation and beating of cream in the butter-making process. *See* Butter.

CHURNS. *See* also Cans.

Refs.: B.S. 1484 (1948); Stoate (1951), *JSDT*, **4**, 151 (design); Wolfrum (1949), *IDC*, **3**, 565.

CHURNS (CANS), CLEANING AND STERILISING. The efficient cleaning of churns, as of all dairy utensils, requires the following steps: (*a*) the removal of gross milk residues by an adequate pre-rinse. Long-draining of the milk, *e.g.* 30 sec., is an appreciable aid to pre-rinsing. (*b*) The removal of remaining milk, greasy films, etc., by hot detergent (usually 1 per cent. at about 160° F.). (*c*) The removal of detergent residues by a hot rinse, about 200° F. (*d*) Sterilisation by steam or other agents, *e.g.* chlorine. (*e*) Drying of the churn by hot air or standing the hot churn open for about 1 min.

Churns are washed by : (i) Hand, using a turk's head brush. (ii) Small churn washers of various constructions. (iii) Rotary washers (Figs. Cu 1 and 2). (iv) Tunnel washers (Figs. Cu 3 and 4).

Generally speaking (iii) and (iv) give the best results.

There is no real reason why hand washing should not give good churns, but with inefficient labour a machine will deliver a better churn. The commonest causes of bad churns are : (i) Too short treatment, especially by steam. (ii) Rinses too cold. (iii) Recontamination by splashing. (iv) Failure to cleanse the lids. (v) Failure to " dry off " the churns.

Although the official test for churns is limited to a rinse test for bacteria, the efficient cleansing of churns should involve not only removal or destruction of bacteria, but also removal of anything which might serve as a breeding ground for them (*e.g.* traces of milk, yellow slime or milk stone). A churn which is " sterilised " but contains such residues will rapidly deteriorate in hygienic condition, whereas a churn which has not been so effectively " sterilised ", but is absolutely free from milk, etc., and is dry, will not deteriorate.

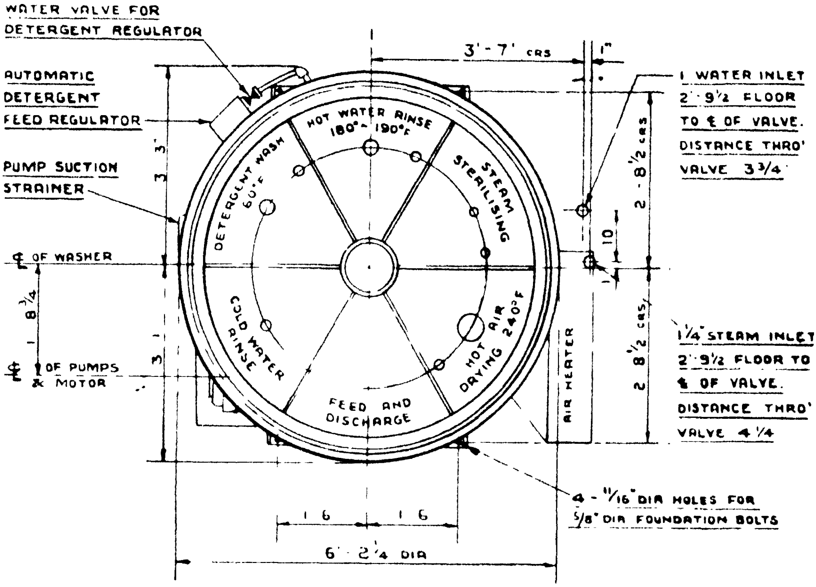
One aspect which has not hitherto received much attention is that of effect of atmospheric temperature on the bacterial condition of utensils. The warmer the weather the more rapidly will utensils, like milk, deteriorate, but this is not generally realised.

To sum up, therefore, the care of utensils involves : (i) Removal of all traces of milk, etc. (ii) Destruction or removal of bacteria. (iii) Drying of the utensil. (iv) Keeping the utensil as cold as possible.

From the bacteriological point of view the sterilising or removal of bacteria is brought about by two agencies : (*a*) Removal by washing. (*b*) Killing of residual bacteria by heat (hot water and steam) and detergent (sometimes also by chlorine).

Scientific Churn Washing. *Pre-rinsing.* Mains water is usually used for this and run to waste. Ideally, the water should be warm enough to melt the fat but not so hot that protein and calcium salts are deposited, *i.e.* between 100° and 120° F. Usually 1 to 2 gal. at a pressure of 30 lb. per sq. in. is sufficient, the operation lasting about 15 sec. The obvious test is to see if the last drainings are free from milk.

Not all machines wash the outside of the churn. There can be no doubt that vigorous brushing would be beneficial for both churns and lids—inside and outside—but brushes so used very quickly become foul and the mechanical difficulties are enormous. The trend of design in churn washing will inevitably be towards more efficient jetting, *i.e.* higher pressures and longer times of treatment.


WATER VALVE FOR DETERGENT REGULATOR
AUTOMATIC DETERGENT FEED REGULATOR
PUMP SUCTION STRAINER
℄ OF WASHER
8 1/4
℄ OF PUMPS & MOTOR
3'-3"
3'-3"
3'-7" CRS
1"
1 WATER INLET 2'-9½ FLOOR TO ℄ OF VALVE. DISTANCE THRO' VALVE 3¾
2'-8½ CRS
10
2'-8½ CRS
1¼" STEAM INLET 2'-9½ FLOOR TO ℄ OF VALVE. DISTANCE THRO' VALVE 4¼
HOT WATER RINSE 180°-190°F
STEAM STERILISING
DETERGENT WASH 60°F
COLD WATER RINSE
HOT AIR DRYING 240°F
FEED AND DISCHARGE
AIR HEATER
4 - 11/16" DIA HOLES FOR 5/8" DIA FOUNDATION BOLTS
1' 6
1' 6
6'-2¼ DIA

PLAN WITH HOOD REMOVED SHOWING OPERATING STAGES

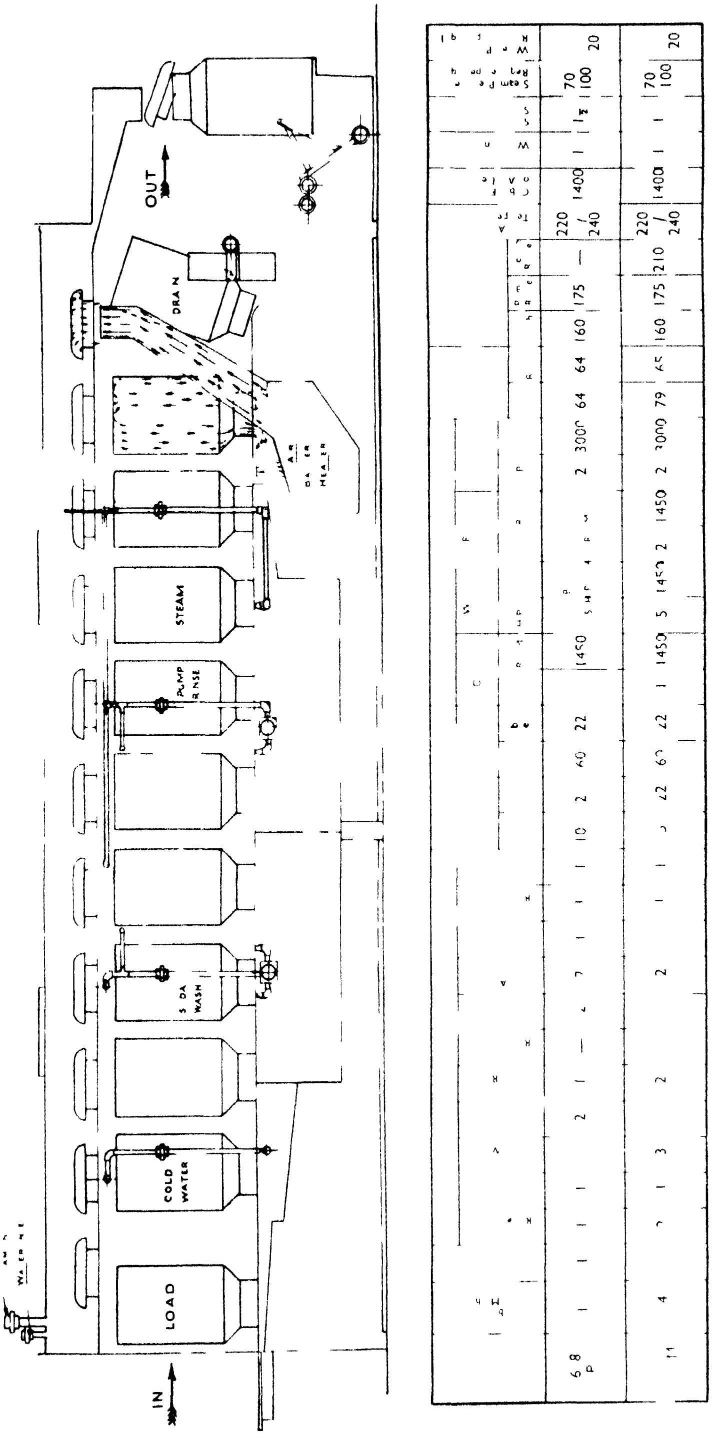
[*By courtesy of U.D. Engineering Co. Ltd.*

FIG. Cu 2.—*Arrangement of* 3 *c.p.m. Rotary Churn Washer.*

The washing of the outside of the churn, which is often plastered with dried-on dung, etc., inevitably leads to serious contamination of the washer and the detergent and hot rinse solutions unless extreme care is taken. Contamination by splashing is naturally more likely in the tunnel type of washer than in the rotary, as a powerful jet impinging on the side of a churn may send spray right through the tunnel.

Failure to give an adequate pre-rinse will mean that milk solids will become coated on the churn and so accelerate the formation of milk stone and possibly yellow slime.

Detergent wash. Some dairies do not use detergent for churn washing and one well-known make of tunnel washer is frequently used without detergent, but with an extra hot rinse in its place. Local circumstances will be the deciding factor in this question. In the writer's experience extra fuel may be required in the absence of detergent; otherwise the churns may develop a smell.



[By courtesy of Wright Dairy Equipment Co

FIG Cu 4 —Diagrammatic Sequence of Can-washing Treatments

Owing to the fact that there is no danger of cracking, as with bottles, the detergent can be used at a temperature higher than in bottle-washing machines. In churn washers the detergent is commonly used at a temperature of 165° F. or thereabouts. As tinned steel churns are universally used in this country, caustic soda cannot be used. Churn-washing detergents are usually based on mixtures of sodium carbonate and sodium metasilicate. Otherwise sodium sulphite (10 per cent.) may be incorporated to prevent corrosion of the tin. In practice detergent strength rapidly falls, due chiefly to carry-over and dilution of the detergent solution by water from the steam used for maintaining its temperature. The hot rinse may in fact become a stronger detergent than the so-called detergent after about 2 hours' running, unless its strength is maintained by " topping up ". *See* Detergents.

Hot rinse. This should be as hot as possible, and at least 200° F.

Steam. This is the crucial stage. Poor rinsing, etc., can be partly compensated by a very efficient steaming, but ineffective steaming usually gives a churn of high bacterial count. A very simple test is to feel the *necks* of the churns as they come off the washer: if the bare hand can be held on the churn neck or shoulder the steaming has been inadequate. A further test is the ability of the churn to " dry itself off " in ½ min. if the lid is left off or replaced at half-cock.

Hot air. Many churn washers fit this as a final stage. If efficient it is a valuable aid to getting a dry, sterile churn, but the writer prefers an effective steaming to a half-hearted hot air treatment.

Test for Sterility of Churns. All tests for sterility of utensils consist essentially in removing the micro-organisms from a given area, either by rinsing or by swabbing, and estimating either their numbers by a plate count, or their activity by some such test as the resazurin test (*q.v.*) or the milk souring organisms test (*q.v.*).

At present, the official test is a plate count on a rinse sample taken from ½ to 1 hr. after washing. The churn should be examined for milk residues, yellow slime, and any other obvious defect, and also recorded as dry, moist, or wet (pools of water).

Technique of rinsing. Five hundred ml. of sterile, quarter-strength Ringer solution are poured into the lid and then into the churn. The lid is then replaced and the churn rolled twelve times through one complete revolution. After 5 min. the rolling is repeated and the rinse sample poured direct into a sterile container. The rinse should be plated within 6 hr. (or refrigerated until the next morning) in yeastrel agar and the plates held 48 hr. at 37° C. The churns are graded as shown below.

Colony count per churn	*Classification*
Not more than 50,000	Satisfactory
Over 50,000 and less than 250,000 . .	Fairly satisfactory
250,000 or over	Unsatisfactory

A " wet " churn is degraded to the next lower category. *See* Cans; Clean milk production; Cleaning and sterilising; Detergents; Surface to volume ratio.

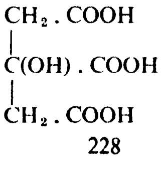
Refs.: *LCDP*; Hall (1953), Qrt. Bull. Mich. Agr. Exp. Sta., **35,** 461; Davis (1948), *JRSI,* **68,** 547; Hoy and Neave (1954), *SAB,* **17,** ii, and in press (chemical sterilisation); Hughes and Ellison (1948), *SAB,* p. 22 (flora); Jones (1947), *SAB,* p. 13 (seasonal variation); Enock (1949), *JSDT,* **2,** 236 (machines).

CHYMASE. *See* Rennet.

CHYMOSIN. *See* Rennet.

CITRATE UTILISATION (KOSER) TEST. *See* Coliforms.

CITRIC ACID.



$$\begin{array}{l} CH_2.COOH \\ | \\ C(OH).COOH \\ | \\ CH_2.COOH \end{array}$$

This tribasic acid occurs to the extent of 0·2 per cent. in milk and is, perhaps, a curiosity as the reason for its presence is not understood. Calcium citrate is only sparingly soluble. Citric acid is formed from glucose by *Aspergillus*, *Penicillium*, and *Mucor* and is of special interest in dairying as the precursor of diacetyl (p. 388) the chief flavour constituent of butter (*see* Beynum and Pette (1939), *JDR*, **10**, 250).

It is most conveniently estimated by Lampitt and Rooke's pentabromoacetone method (A (1936), **61**, 654).

Refs.: Prescott and Dunn; Stephenson; Babad and Shtrikman (1951), *JDR*, **18**, 72 (estimation).

CITROMYCES. A name formerly given to certain moulds producing citric acid. They are now included in *Penicillium*. *See* Moulds.

CLADOSPORIUM. A genus of mould producing red and brown pigments which may stain wood. *See* Butter; Moulds.

CLARIFICATION. A centrifugal method of removing dirt, cells, pus, blood, etc., from milk. The clarifier is essentially the same as the cream separator (*see* Separators). The fat and skim are, however, not separated, but the deposit corresponds to the separator slime. It is an alternative to filtration, and is sometimes preferred by dairy managers. Milk is usually clarified at a temperature of 90° to 100° F.

Clarification has been largely discontinued in this country, largely on account of troubles developing with clarifiers. Anyone who has seen the amount and nature of the slime which is removable from, say, 1000 gal. of commercial bulk milk would inevitably be in favour of clarification of all milk. Obviously filtration as ordinarily practised removes only a small fraction of this slime. The latest development is towards the use of very high speeds which improves milk bacteriologically by throwing down the larger bacterial cells. *See* Stability; Sterilised milk.

Refs.: Simonart and Debeer (1953) NMDJ **7**, 117.

CLARIFIER SLIME. The solid matter, heavier than milk, which is removed by centrifugal clarification. It consists of "dirt", body cells, bacteria, hairs, blood cells, etc., and is of repulsive odour and appearance.

CLASSIFICATION IN DAIRY BACTERIOLOGY. General Principles. In Table Cl I is given a simple classification of bacteria which includes all the organisms of importance in dairying. Only those groups of bacteria of interest to the dairy scientist have been included and, furthermore, the differentiation has been placed upon a broad basis and from the point of view of quite simple tests.

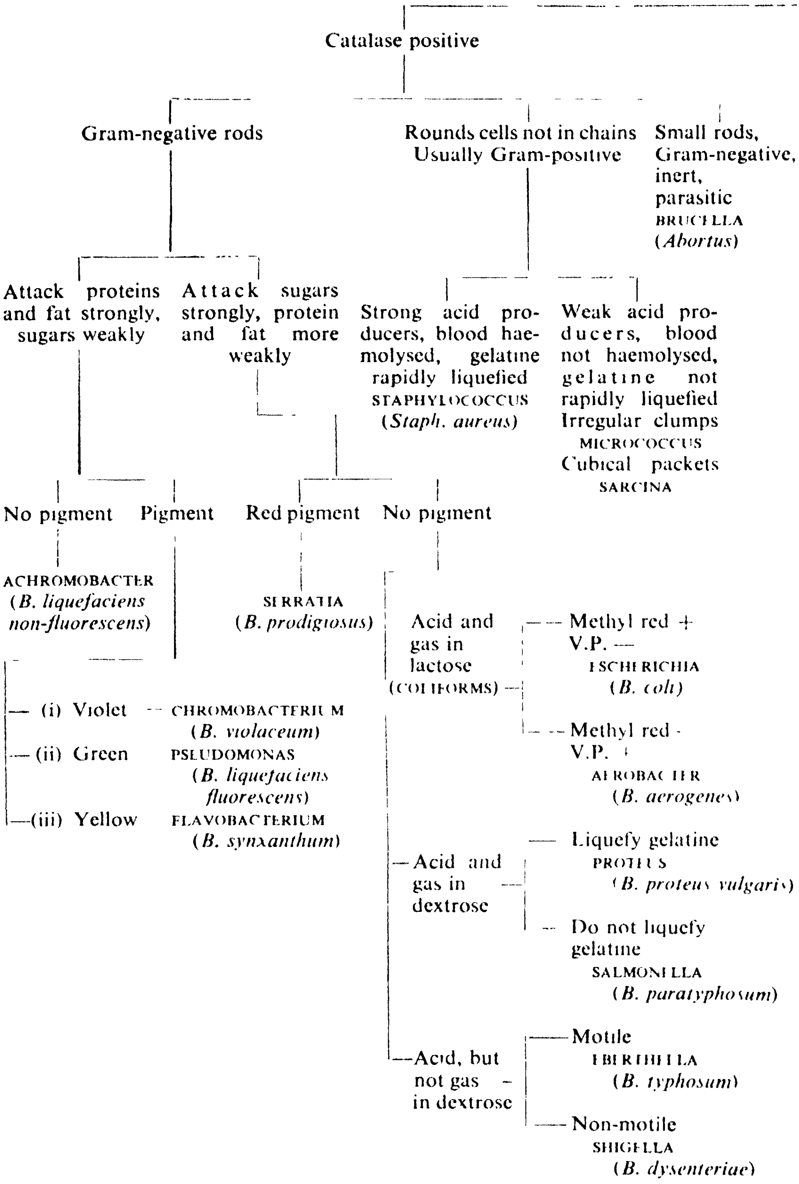
It is important in economic bacteriology to consider micro-organisms from a broad point of view. Thus, for example, the broadest distinction that the dairy bacteriologist should bear in mind is that between (i) those types which attack sugar strongly, protein and fat weakly, are usually catalase negative and prefer anaerobic or micro-aerophilic conditions; and (ii) types attacking proteins and fat strongly, sugars weakly, are always catalase positive, and prefer aerobic conditions. Naturally there are types which combine both sets of characteristics or possess neither, but, generally speaking, types of interest to the dairy scientist fall into one or other group.

These contrasted types may be antagonistic one to the other, the first, quite commonly, by removing air and forming acid, and the second, rarely, by producing an alkaline reaction. This broad division is illustrated in Table Cl I, where the streptococci and lactobacilli, and to a less extent the propionic acid bacteria and coliforms, etc., represent type (i), and the pigment-forming Gram-negative rods and the aerobic spore formers (*Bacillus*) represent type (ii).

It is important, therefore, in classification to proceed from broad concepts and sets of characteristics down to the more detailed properties of micro-organisms, such as position and number of flagella, fermentation of specific sugars, colony, TABLE

SIMPLE

(*Non-spore-forming*

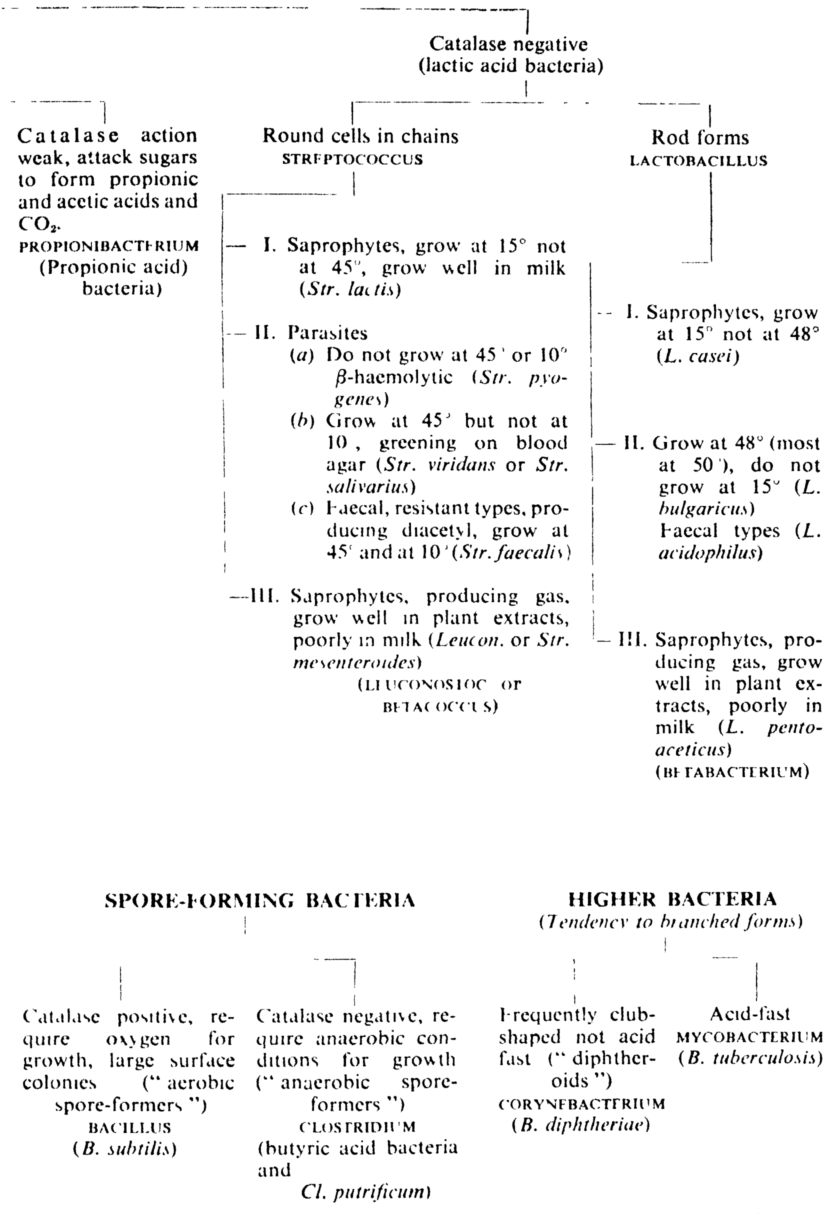


CLASSIFICATION IN DAIRY BACTERIOLOGY

Cl I

BACTERIA

and non-branching)



Catalase negative (lactic acid bacteria)

Catalase action weak, attack sugars to form propionic and acetic acids and CO_2.
PROPIONIBACTERIUM
(Propionic acid) bacteria)

Round cells in chains
STREPTOCOCCUS

— I. Saprophytes, grow at 15° not at 45°, grow well in milk (*Str. lactis*)

— II. Parasites
- (*a*) Do not grow at 45° or 10° β-haemolytic (*Str. pyogenes*)
- (*b*) Grow at 45° but not at 10°, greening on blood agar (*Str. viridans* or *Str. salivarius*)
- (*c*) Faecal, resistant types, producing diacetyl, grow at 45° and at 10° (*Str. faecalis*)

—III. Saprophytes, producing gas, grow well in plant extracts, poorly in milk (*Leucon.* or *Str. mesenteroides*)
(LEUCONOSTOC or BETACOCCUS)

Rod forms
LACTOBACILLUS

— I. Saprophytes, grow at 15° not at 48° (*L. casei*)

— II. Grow at 48° (most at 50°), do not grow at 15° (*L. bulgaricus*)
Faecal types (*L. acidophilus*)

— III. Saprophytes, producing gas, grow well in plant extracts, poorly in milk (*L. pentoaceticus*)
(BETABACTERIUM)

SPORE-FORMING BACTERIA

Catalase positive, require oxygen for growth, large surface colonies ("aerobic spore-formers")
BACILLUS
(*B. subtilis*)

Catalase negative, require anaerobic conditions for growth ("anaerobic spore-formers")
CLOSTRIDIUM
(butyric acid bacteria and *Cl. putrificum*)

HIGHER BACTERIA
(Tendency to branched forms)

Frequently club-shaped not acid fast ("diphtheroids")
CORYNEBACTERIUM
(*B. diphtheriae*)

Acid-fast
MYCOBACTERIUM
(*B. tuberculosis*)

Each term printed thus: BACILLUS *represents a* Genus *or homogeneous group of species or types. The names in brackets, thus:* (*B. coli*) *are of the best-known species or types (common name) or, in some cases, the common name of a group or* Genus.

type, etc., which are often highly variable and liable to considerable subjective error in their determination.

Examination of Table Cl I in conjunction with Tables Cl II and Cl III will show the investigator which tests are of importance (*a*) for the differentiation of the *genus* (a group of species closely resembling one another) from other *genera*, and (*b*) for identifying the particular species in the *genus*. Many hundreds of tests have been described in textbooks and original papers, but many of these are so involved that any attempt at classification results in a special piece of research. The most useful tests have been selected, and the grouping given in Tables Cl IV and Cl V shows how the maximum of information may be obtained from the minimum of experimental work. The tests fall into three groups: A. Preliminary, B. Culture in Selected Media, and C. Special Experiments.

TABLE Cl II

CHARACTERISTICS FOR DIFFERENTIATING *Genera* ARRANGED IN ESTIMATED ORDER OF IMPORTANCE.[1]

(1) Gram stain
(2) Arrangement and shape of cells
(3) Reactions in dextrose broth
(4) Reactions in lactose broth
(5) Reactions in gelatine
(6) Formation of acetoin
(7) Formation of pigment
(8) Aerobic and anaerobic growth
(9) Reduction of nitrate to nitrite

[1] Tests for the presence of spores and of catalase are used for the first broad differentiation and can hardly be compared with the tests listed above.

TABLE Cl III

CHARACTERISTICS FOR DIFFERENTIATING SPECIES (OR TYPES) IN A *Genus* ARRANGED IN ESTIMATED ORDER OF IMPORTANCE

(1) Rate and type of liquefaction in gelatine
(2) Reactions in litmus milk
(3) Motility
(4) Pigment formation
(5) Fermentation of sucrose
(6) Fermentation of mannitol
(7) Fermentation of dextrose
(8) Fermentation of lactose
(9) Reduction of nitrate to nitrite
(10) Fermentation of maltose
(11) Fermentation of glycerol
(12) Fermentation of pentoses
(13) Temperature range of growth
(14) Oxygen requirements
(15) Fermentation of raffinose
(16) Formation of indole
(17) Gram stain
(18) Production of hydrogen sulphide
(19) Formation of acetoin
(20) Type of growth on potato

TABLE Cl IV

PROCEDURE FOR IDENTIFICATION OF A BACTERIUM

Experiment	*Information gained*	*Further tests of this type required*
	A. *Preliminary*	
(1) Streaking for surface colonies on agar medium	(i) Rate of growth (ii) Type of colony (iii) Pigment (iv) Catalase (by hydrogen peroxide) (v) Odour (vi) Motility	
(2) Microscopical examination of 24-hr.-old colony by Gram and methylene blue stains	(i) Type of cell (ii) Gram reaction (iii) Internal structure (iv) Spores	(*a*) Acid-fast (*b*) Spore stain (in doubtful cases) (*c*) Flagella stain

TABLE CI IV (*contd.*)

B. *Culture in Selected Media*

(3) Litmus milk (4) Yeast dextrose litmus milk	(i) Acid or alkali
	(ii) Clot by acid or rennin
	(iii) Peptonisation
	(iv) Fermentation of lactose and dextrose
	(v) Sliminess or ropiness
(5) Gelatine	(i) Rate of liquefaction
	(ii) Type of liquefaction
(6) Dextrose broth	(i) Acid
	(ii) Gas
	(iii) Acetoin (Voges-Proskauer reaction)
	(iv) Methyl red (*p*H of $<$ 5·6)
	(v) Motility
(7) Bile salt lactose broth	(i) Acid
	(ii) Gas
	(iii) Growth in presence of bile
(8) Plain peptone water (no sugar)	(i) Ability to grow in absence of sugar.
	(ii) Formation of alkali (ammonia)
	(iii) Production of indole
	(iv) Production of hydrogen sulphide
	(v) Motility
(9) Nitrate broth	(i) Reduction to nitrite
	(ii) Reduction to ammonia
(10) Potato (neutralised)	(i) Type of growth
	(ii) Pigment
(11) Blood agar (deep plating)	(i) True (β) haemolysis
	(ii) Greening, etc. (α and α^1 types)
	(iii) Value of blood for growth
(12) Unfiltered malt extract	(i) Growth
	(ii) Acid
	(iii) Gas

C. *Special Experiments*

(13) Growth in stab culture	(i) Oxygen requirements	Culture under controlled anaerobic conditions
	(ii) Type of growth in stab	
(14) Growth at temperatures 10°, 15°, 37°, 45°, and 50°	(i) Temperature range of growth	
(15) Heat to 60° for 30 min	(i) Heat resistance	(*a*) Heat to 65° for 30 min. or 80° for 10 min. (or higher for detection of spores)

Methods. For the purpose of illustrating the general procedure when an unknown organism is to be identified, we shall suppose that a retailer of liquid milk has received complaints of poor keeping quality from his customers. The problem is immediately handed over to the bacteriologist employed by the firm, who tackles the problem in the following way. Samples of the milk returned by the customer are plated in milk agar, duplicate plates incubated at 22° and 37° C. (an important

TABLE CI V.—CHARACTERISTICS OF IMPORTANCE IN DETERMINING *Genus* OF AN ORGANISM (*Cf* Table CI I)

Fundamental metabolic characteristics	*General description*	*Genus*	*Spores*	*Catalase*	*Gram stain*	*Cell shape*	*Motility*	*Dextrose broth*	*Lactose broth*	*Gelatine liquefaction*	*Acetoin formation*	*Pigment formation*	*Oxygen requirements***	*Reduction of nitrate to nitrite*
Intermediate	Cocci	Staphylococcus	0	+	+	Round	0	A	A	+			2	±
Attacking primarily protein and fat		Micrococcus	0	+	+	,,	0	Sl	0	+			2	±
		Sarcina	0			,,	+	Sl	0	+			2	±
	Air and water organisms	Achromobacter	0	+	0	Rod	+		+			0	2	+
		Chromobacterium	0		0		+	0	0			Violet	2	±
		Pseudomonas	0		0	,,	+	0				Green	2	±
		Flavobacterium	0	+	0	,,		±				Yellow	2	±
Intermediate		Serratia	0		0	,,	+	A G	A G	+		Red	2	+
Attacking primarily sugars	Intestinal and pathogenic types	Escherichia	0		0			A G	A G	0	0	0	2	+
		Aerobacter	0		0			A G	A G	0*	+	0	2	+
		Proteus	0		0	,,	+	A G	0		+	0	2	+
		Salmonella	0		0		+ *	A G	0	0	0	0	2	+
		Eberthella	0		0	,,		A			0	0	2	+
		Shigella	0		0		0	A		0	0	0	2	+
Inert	Miscellaneous	Brucella	0		0			0	0	0		0	2	+
		Alcaligenes	0	+	0			0	0		0	0	2	∓
Intermediate		Bacterium***	0										2	
		Microbacterium	0		+		0	±	+	+		±	2	+
Attacking primarily sugars		Propionibacterium	0	+ *			0	A G		0		±	4	0
	Lactic acid bacteria	Streptococcus	0	0	+	Round	0	A	A *	0*		0	3 & 4	0
		Lactobacillus	0	0	+	Rod	0	A	+	0		0*	3 & 4	0
Attacking primarily protein and fat	Spore formers	Bacillus		+		Rod		+	±	+		∓	1	+
		Clostridium	+	0	+		+	+		+		∓	5	0

0 = Negative reaction — + Positive reaction — ± — Usually positive — ∓ — Usually negative

A G Acid and gas — A Acid — Sl — Slightly acid — * — Occasional exceptions

** 1 = Obligate aerobe — 2 Prefer air — 3 = Indifferent — 4 = Prefer little or no air — 5 = Obligate anaerobe

***Really a dumping ground for rod types not acceptable in other *genera*. It is therefore very heterogeneous.

point) and examined after 48 hr. Both sets of plates are found to yield colonies of a characteristic type, *e.g.* medium size, smooth, glistening, and yellowish; other types are rare. (Finding an organism in almost pure culture is not infrequent when clear-cut faults are encountered.) Using a low-power microscope, a well-isolated colony is touched with a sterile loop and this streaked on a hardened milk agar plate which has been poured some hours previously, and the plate incubated at 30° C. (This is a safe temperature for almost all bacteria of importance in dairying.) A small portion of the same colony is then touched again with a loop, rubbed up in a drop of tap water on a clean slide, the smear carefully dried by passing to and fro over a yellow bunsen flame and finally stained by borax methylene blue. On microscopical examination, characteristic cubical packets of rather small cocci are seen. Finally, dilute hydrogen peroxide (*c.* 3 vol. or 1 per cent.) is poured on to the *original* plate. All the colonies immediately begin to effervesce vigorously. The information thus found is sufficient for the experienced worker to identify the type of organism, but we shall proceed to discuss the identification procedure step by step in full detail.

Purification of the Culture. Before proceeding to identify the organism it is essential to obtain a pure culture. Broadly speaking, there are two methods: (*a*) single-cell technique, in which a single cell is separated from the rest and inoculated into a sterile medium; (*b*) exhaustive plating and/or streaking, For practical purposes it is recommended to emulsify a well-isolated colony and plate three times. The colony finally picked off may be assumed to be a pure culture.

Preliminary Tests (*see* Table Cl IV). Streak the purified milk or broth culture on hardened plates of milk, beer wort (or malt), and nutrient (sugar-free) agar media (*p*H 6·8). Incubate at 30° C. and observe the characteristics detailed in Table Cl IV. Exp. 1 (i-v) gives considerable information about the nature of the organism. Thus moulds are easily recognised by their appearance; yeasts usually give large, smooth, glistening, raised colonies with a fruity smell; actinomyces a dry white or brownish raised colony with a typical summer "earthy" smell; and aerobic spore-formers "lead white," spreading colonies. Lactic acid bacteria usually give small colonies on the first two media and fail to grow on the sugar-free medium. In addition, yeasts and cocci are frequently coloured (pink, orange, or yellow) and the pigment-forming Gram-negative rods give colonies with their characteristic colours (Table Cl I).

Motility. Little difficulty is usually experienced in detecting the motility of such types as *Pseudomonas* and other actively motile organisms. Unless 24-hr. broth cultures yield obviously motile cells, the following procedure should be adopted: Inoculate various broth and agar media and incubate at 22° C. and 37° C. Examine with the hanging drop preparation after 2, 4, 8, 16, and 24 hr., maintaining the 37° C. cultures at blood heat on a warm stage. Do not confuse the ordinary Brownian motion with true motility.

Microscopical Examination. Stain smears of 24-hr. agar slope (or stab) cultures by Gram's method as follows: *Solutions required:* (*A*) 10 ml. saturated alcoholic gentian violet, 90 ml. 0·5 per cent. phenol. (*B*) 1 g. iodine, 3 g. potassium iodide, 300 ml. water. (*C*) Neutralised alcohol. (*D*) 0·5 per cent. neutral red.

Method. After fixing the smear by gentle heat, add solution *A* drop by drop through a filter paper in a funnel, and stain for 3 min. Then wash off the stain with solution *B* and leave this solution on the smear for 1 min. *On no account wash off with water before adding the iodine.* Wash next with alcohol for 15 to 30 sec. or until the washings are colourless. Wash gently under the tap and finally stain with solution *D* for 30 sec. Wash and dry. Cells that are black or purple are Gram-positive, those red or pink Gram-negative. (Bartholomew and Mittwer (1952), *BR*, **16,** 1.)

Spore and Acid-fast Stains. The following may be used both as an acid-fast and as a spore stain.

Solutions required: (*A*) Dissolve 0·1 g. fuchsin in 10 ml. alcohol in a mortar (with grinding), dissolve 5 g. phenol in 90 ml. water and with this rinse the alcoholic fuchsin into a bottle. (*B*) 0·75 g. borax, 3 g. methylene blue, 300 ml. water.

Method. Clean the slide by immersing in alcohol-ether or by flaming, dry the smear, add solution *A* through a filter paper in a funnel, place the slide on a hot plate and " steam " for 5 min., keeping the smear covered with the staining solution. Wash, immerse in 25 per cent. sulphuric acid for 30 sec., wash, immerse in alcohol-ether for 30 sec., and repeat the acid treatment until the smear is a very faint pink. Finally wash, stain with solution *B* for 30 sec., wash and dry at room temperature.

Spores will appear as red oval or round cells and acid-fast bacteria as red rods. Non-acid-fast bacteria will be pale blue.

For flagella stains *see* Eyre or Chalmers.

For the routine staining of milk films either borax methylene blue or Newman's stain may be used.

Newman's Stain. 1 g. methylene blue, 54 ml. 95 per cent. alcohol, 40 ml. tetrachlorethane, 6 ml. glacial acetic acid. Mix the first three at 70° C., cool, add the acid, and filter.

With the completion of these preliminary tests, it is possible to assign the unknown organism fairly accurately to a particular *genus*, or at least to one of a few *genera*. Thus the organism cited for illustration purposes would have been found to have the following properties (*cf.* Table Cl IV) : 1. (i, ii, and iii) Yellow colonies growing rapidly on ordinary agar media. (iv) Powerful catalase reaction. (v) Unpleasant odour (" mild stink "). (vi) Non-motile. 2. (i) Small round cells in cubical packets. (ii) Gram-positive, non-acid-fast, no spores, and no flagella.

This evidence is sufficient to label the organism as of the *Sarcina lutea* type, common in dirty utensils as it is fairly resistant to heat and detergents.

Normally the investigator would proceed to work through Table Cl IV—*B* and *C*, but if he only desires to ascertain to what genus the organism belongs, it is sufficient to complete the requirements of Table Cl II by determining the reactions in dextrose and lactose broths and in gelatine, the formation of acetoin, reduction of nitrate to nitrite, and the oxygen requirements.

Sugar Broths. *Medium.* 5 g. sugar ; 10 g. peptone ; 50 ml. autolysed yeast ; 10 ml. 1 per cent. litmus solution or 50 ml. 0·04 per cent. bromcresol purple ; 1000 ml. tap water.

Heat to dissolve, adjust to *p*H 6·8, add the indicator solution, filter, fill out into test-tubes containing fermentation tubes, and sterilise by three steamings or momentary autoclaving. Inoculate and incubate for 14 days at 30° C. (or the found optimum temperature of growth). Examine after 1, 2, 4, 7, and 14 days, and record acid and gas. Reactions in dextrose and lactose are of first importance in differentiating the *coli-typhoid* genera.

Detection of Acetoin. Inoculate dextrose broth (without indicator), incubate at 30° C. and at intervals withdraw aseptically 1 ml. of the broth to a test-tube, add a knife-point of creatine and 1 ml. of 40 per cent. sodium hydroxide. Shake gently. The appearance of a pink colour in 1 to 30 min. indicates the formation of acetoin.

Gelatine. Stab-inoculate two tubes of gelatine and incubate one at 22° C. and the other at 37° C. Examine every day at 22° C., recording the type of liquefaction. After 14 days, cool the 37° C. culture in ice water and test for liquefaction by tilting.

Aerobic and Anaerobic Growth. For practical purposes stab cultures in agar media will indicate the oxygen requirements of the organism. Most protein- and fat-attacking types prefer air, and some sugar-attacking types prefer little or no air. The term "anaerobe" commonly refers to the anaerobic spore-forming rods (*Clostridium*), and these do not grow on agar plates incubated normally, *i.e.* aerobically.

Reduction of Nitrate. *Nitrate broth.* Add 0·1 per cent. potassium nitrate (nitrite-free) to Lemco broth (1 per cent. peptone and 0·5 per cent. Lemco in tap water). If no growth is obtained, add 0·2 per cent. dextrose to the medium.

Test solutions. (*A*) 30 per cent. glacial acetic acid saturated (hot) with sulphanilic acid ; (*B*) 6 g. dimethyl-α-naphthylamine, 1000 ml. 30 per cent. glacial acetic acid.

Method. To about 10 ml. of the inoculated and incubated (7 days) nitrate broth add 1 ml. of *A* and 1 ml. of *B*. Shake. The appearance of a cherry-red colour indicates reduction of nitrate to nitrite. In this, as in all other tests, it is essential to carry out identical tests on *uninoculated and incubated control media.*

Examination of Table CI V will now enable the worker to place the organism in a *genus*, provisionally at any rate. For convenience the reactions of the *genera* dealt with are given in Table CI V.

Micro metabolic methods. Considerable time and money can be saved by using micro metabolic methods for determining sugar fermentations and other biochemical reactions.

Refs.: Davis (1939) ZB II, **101**, 97; Clarke and Cowan (1952) JGM **6**, 187; Cowan (1953) LP **2**, 241.

Tests for Differentiating Types or Species (other than those already described for Differentiating Genera). *Growth in Litmus Milk Media.* Inoculate into litmus milk and yeast dextrose litmus milk. Incubate at 30° C. and record after 1, 2, 4, 7, 10, and 14 days.

Code :

A ? *or* sl. A = weak acidity
A = acidity
A + = strong acidity
V = viscous
C = clot
NC neutral (rennet) clot
p = slight peptonisation
P = peptonisation
P + = strong peptonisation (*i.e.* mostly whey)

g = slight gas
G = vigorous gas
ak ? *or* sl. ak = weak alkalinity
ak = alkalinity
ak + = strong alkalinity
r = partially reduced
r¼″ = partially reduced to ¼″ from surface
R 1″ = reduced to 1″ from surface
R = completely reduced

Temperature Range of Growth (pp. 582, 892 and 1022).

Formation of Indole. Indole is a decomposition product of tryptophane, itself an amino acid and a decomposition product of proteins.

Solutions required :

A.	Paradimethylaminobenzaldehyde	4 g.
	96 per cent. alcohol	380 ml.
	Conc. hydrochloric acid	80 ml.
B.	Sat. aq. potassium persulphate.	

Method. Culture the organism in peptone water (1 per cent. peptone, 0·5 per cent. salt—no sugar) at the optimum temperature—usually 30° to 40° C. A " tryptone " type of medium is advantageous, as the tryptophane content will be higher. At intervals of two days withdraw aseptically 1 ml. of culture medium into a test-tube and add 1 ml. of soln. A. A bright red coloration indicates the presence of indole. The colour is usually intensified by warming and by the addition of 1 ml. of soln. B. The red dyestuff is soluble in chloroform.

Detection of Hydrogen Sulphide. This test may be considered as a partner to the indole test, as both hydrogen sulphide and indole are split off from " peptones " by the typically putrefactive bacteria. The same medium may be used, provided that it is fairly rich in cystine, etc. The most convenient way of detecting H_2S formation is to soak strips of filter paper in 1 per cent. lead acetate solution, dry, and insert with the cotton-wool plug of the test-tube. Alternatively 1 ml. of medium may be withdrawn and added to 1 ml. of the lead acetate solution. In either case a brown or black coloration indicates H_2S formation. In both indole and H_2S tests it is essential to have negative controls (*i.e.* on uninoculated media) and advisable to have positive controls (*i.e.* with organisms such as *E. coli* which produce both indole and H_2S).

Growth on Potato. This is one of the most characteristic features of many organisms and is a classical test in bacteriology. Pigment on potato is an especially valuable feature, as some organisms fail to produce pigment on ordinary agar media but do so on potato. As potato is naturally acid, and many organisms are inhibited by acid, potato strips should always be soaked in sodium bicarbonate —the so-called " neutral potato ".

Method. Wash fairly large potatoes, peel and remove eyes. Cut cylinders by means of a large cork borer and cut each cylinder obliquely in half so as to form two wedge-shaped pieces. Soak for 3 hr. in 1 per cent. sodium bicarbonate solution. Place a small piece of cotton-wool moistened with 5 ml. of 5 per cent. glycerine in water in the bottom of the tubes. Large test-tubes or boiling tubes should be used. Steam at 100° C. for ½ hr. on three successive days.

Blood Agar (*see* p. 79).

Unfiltered Malt Extract (10 per cent.). Chalk must *not* be added.

Heat Resistance. The primary considerations in determining the heat resistance (sometimes loosely called the " thermal death point " [T.D.P.]) of an organism are: (1) Control of temperature and time; (2) Medium; (3) *p*H of medium.

The most suitable conditions for dairy bacteriologists to use are heating to various temperatures, *e.g.* 55°, 60°, 65 C., etc., for ½ hr. in normal milk whose *p*H lies between 6·5 and 6·7. A standard inoculation, *e.g.* 1,000,000 cells per ml., should be used. The inoculated milk may either be sealed in a capillary and immersed in a water bath for ½ hr. or held in a test-tube (10 ml.) immersed to the neck. The exact temperature is recorded on a thermometer in a control milk tube. After cooling, the milk may be plated on a suitable medium, or, more simply, the tubes incubated at the optimum temperature. In the latter case 1 per cent. litmus solution may be incorporated in the milk.

Classification into Types or Species. The most important differential characteristics for a number of genera are given in Tables Cl VI to XVI. More detailed information will be found in Bergey and Wilson and Miles.

For the coliforms, lactic acid bacteria and propionic acid bacteria, classifications are given separately.

The normal procedure is to carry out all the tests described in Tables Cl VI to XVI and then to make the best " fit " between the results of these tests and those given for types or species in the tables. The reader may be warned against the danger of focusing attention on one single characteristic, *e.g.* motility, gelatine liquefaction, or specific sugar fermentations. We may compare this with trying

TABLE Cl VI

Staphylococcus.

	Pigment	*Sucrose*	*Mannitol*	*Raffinose*
Staph. aureus . . .	Orange	+	+	0
,, citreus . . .	Lemon-yellow	+	+	+
,, epidermidis . .	—	+	0	0
,, albus . . .	—	+	+	0

TABLE CI VII

Micrococcus

	Liquefaction of gelatine	*Litmus milk*	*Growth on potato*	*Reduction of nitrate*
M luteus	0	sl A	Lemon-yellow	0
,, aurantiacus	0	sl A	Slimy yellow	±
,, cereus	0	0	Dark yellow	0
,, caseolyticus	Infundibuliform	A-P	Scanty, creamy	∓
,, flavus	Crateriform	sl A-p	Scanty, yellow	0
,, cinnebareus	0	sl ak	Vermilion	+
,, roseaceus	Slow	A	Rose red	0
,, freudenreichii	Infundibuliform	ACP	Creamy	0
,, candicans	0	sl A	Scanty, creamy	+
Sarcina flava	Slow	ak	Yellow	0
,, lutea	Infundibuliform (slow)	C-ak	Bright yellow	±
,, lactea	0	sl A	Scanty, grey	+
,, aurantiaca	Infundibuliform	C P	Orange	0

TABLE CI VIII

		Motility	*Liquefaction of gelatine*	*Litmus milk*	*Nitrate reduced to nitrite*
Achromobacterium	liquefaciens		+	0	0
,,	lipolyticum		+	ACP	?
,,	pestifer	+	0	0	+
,,	liquidum	+	+	0	+
,,	halophilum	+	0	0	0
,,	butyri	0		0	0
,,	ubiquitum	0	0	AC	+
,,	aromafaciens	0	0	AP	0
,,	candicans	0	0	ak	0

TABLE Cl IX

	Motility	*Dextrose*	*Growth at 37° C*	*Nitrate reduced to nitrite*
Chromobacterium violaceum	+	A	0	+
,, ianthinum	+	A	+	+
,, amethystinum	+	∓	0	+
,, iodinum	0	0	+	+

TABLE Cl X

	Motility	*Liquefaction of gelatine*	*Litmus milk*	*Nitrate reduced to nitrite*
Pseudomonas aeruginosa (B pyocyaneus)	+	+	NC P ak	
,, fluorescens	+	+	ak	
,, syncyanea	+	+	0	0
,, putida	+	0	0	+
,, non liquefaciens	0	0	0	0

TABLE Cl XI

	Motility	*Liquefaction of gelatine*	*Litmus milk*	*Nitrate reduced to nitrite*
Flavobacterium aquatile	+	+	0	+
,, synxanthum	+	+	ak	0
,, aromaticum	+	+	AC P	0
,, aurantiacum	+	0	0	+
,, butyri	+	0	0	0
,, lactis	+	0	sl A	0
,, arborescens	0	+	R	0
,, proteus	0	0	0	+

TABLE Cl XII

	Sucrose	*Mannitol*	*Maltose*	*Liquefaction of gelatine*
Proteus vulgaris	AG	0	AG	+
,, mirabilis	AG	0	0	+
,, hydrophilus	AG	AG	AG	+
,, morganii	0	0	0	0

TABLE Cl XIII

	Gram stain	*Motility*	*Pig-ment*	*Litmus milk*	*Potato*	*Lique-faction of gelatine*
Bacterium erythrogenes .	+	0	Yellow to red	A–P–ak	Rapid–yellow to red pigment	Slow
,, linens . .	+	0	Orange	ak (slow)	Scanty—orange pigment	+

For description of other types in this ill-defined group *see* Bergey.

TABLE Cl XIV

	Maltose	*Starch*	*Raffinose*	*Litmus milk*	*Growth on agar*
Microbacterium lacticum . .	A	A	0	A	Slightly yellowish
,, mesentericum	A	A	A	0	Slimy
,, flavum .	0	0	0	A?	Yellow

to fit an irregularly shaped cloth over an irregularly shaped table. If we start by taking an arbitrarily selected point of the cloth and pinning it down to one point on the table, the chances of obtaining a good fit are greatly reduced. The common-sense way is to lay the cloth over the table and move it about until inspection demonstrates the position of best fit. For accurate classification it is impossible to know too much about an organism. Exigencies of time require that as much useful information as possible shall be obtained with as few experiments as possible.

See Coliforms; Lactic acid bacteria; Propionic acid bacteria; Thermoduric bacteria; Thermophilic bacteria.

Refs · Bergey; Chalmers; Cunningham; Demeter; Hammer, Orla Jensen; Tanner; Wilson and Miles; Davis (1949), *FM*, **24**, 211.

CLEAN. Literally, free from milk and other residues. Also used loosely to mean free from residues and bacteria (*i.e.* sterilised).

"CLEAN." In relation to live-stock, pure bred.

CLEAN MILK PRODUCTION AND DISTRIBUTION. Spoilage of milk in this country is practically always due to the growth of bacteria. These may sour milk by the production of lactic acid, or cause taints by decomposing the protein and fat to produce evil-smelling substances. Roughly speaking, we may say that when the bacteria have reached a number of about 100,000,000 per ml. (or c.c.) taints will appear and the commercial life of the milk is at an end. Milk in the udder of the healthy cow has a count of under 300 per ml. The difference between this figure and the "critical taint count" of about 100,000,000 is enormous. To prevent the appearance of souring or taint the count must be maintained well below this figure.

In hot weather and on farms where neither an adequate supply of clean, cold (below 60 F.) water nor a refrigeration plant is available, producers may have

TABLE Cl XV

(*Cf.* Gibson (1944), *JDR*, **13**, 248.)

	Growth on agar	*Dextrose broth*	*Acetoin*	*Spore appearance*	*Liquefaction of gelatine*	*Diastase*	*Motility*	*Staining of rods*
Bacillus subtilis	Not rhizoid	A	+	No significant swelling of rod	Rapid	+	+	Uniform
,, pumilus . . .	,,	A	+	,,	,,	0	+	,,
,, licheniformis . .	,,	A	+	,,	Slow		+	,,
,, cereus	,,	A	+	,,	Rapid		+	Contains globules not stained by fuchsin
,, anthracis . . .	,,	A	+	,,	Slow		0	,,
,, megatherium . .	,, Turns yellow	A	0	,,	—			
,, circulans . . .	Not rhizoid	A		Marked swelling of rod	0 or slow			
,, polymyxa . . .	,,	A.G.	+					
,, macerans . . .	,,	A.G.	0					
,, carotarum . . .	,,	O or A ?		Elliptical—no swelling of rod				
,, brevis . . .	,,	,,		Large elliptical—distinct swelling				
,, fusiformis . . .	,,	,,		Round—distinct swelling				
,, pasteuri . . .	Growth promoted by alkalinity and ammonia							
,, mycoides . . .	Rhizoid							

TABLE CLXVI

	Spores	*Rods swollen*	*Motility*	*Liquefaction of gelatine*	*Dextrose*	*Starch*	*Lactose*	*Sucrose*	*Brain medium blackened*
Clostridium butyricum	Not terminal			0	A G	+	+	+	0 (Mannitol +)
,, fallax	,,			0	A G	+		+	0 (,, 0)
,, septicum	,,		+	+	A G	0		0	0
,, sporogenes	,,				A G	0	0	0	+
,, bifermentans	,,	0			A G	0	0	0	+
,, tetani	Terminal			+	0	0	0	0	+
,, putrefaciens	,,	+	0		A G	0	0	0	+

difficulty in keeping their counts down and find that milk is being returned to them. It is possible for milk to be *delivered* with a count of only a few thousand even in hot weather, but it is necessary to know the fundamental essentials of clean milk production to achieve this.

Causes of Poor Keeping Quality. The following are the common causes of unsatisfactory milk, in order of the stages of handling of the milk : (1) Mastitis. (2) Unwashed udders. (3) Unwashed milkers' hands. (4) Unsterilised pails. (5) Dusty atmosphere. (6) Unsterilised and leaky coolers. (7) Failure to cool. (8) Unsterilised churns. (9) Unsterilised storage tanks. (10) Recontamination after pasteurisation. (11) Unsterilised bottling plant. (12) Unsterilised bottles, *i.e.* inefficient bottle-washing machine. (13) Holding bottled milk at high temperature (over 60° F.).

(1) *Mastitis.* Infected cows frequently yield milk having a count of many thousands as it leaves the udder. Sudden failures to achieve a satisfactory standard have often been traced to this in the absence of other causes. For the farmer complete eradication is difficult. There is no reason, however, why an intelligent person should not achieve a satisfactory measure of control by the simple process of systematically using the strip cup (Fig. Ce 1), and bromcresol purple paper tests. Cows giving milk reacting to these tests should be placed in a standing apart from other animals and milked last. If the milk is to be used for cheesemaking or consumed raw, this mastitis milk should preferably not be mixed with the bulk milk but should be pasteurised by direct steam injection and fed to pigs or other livestock. *See* Mastitis.

(2) *Unwashed udders* and (3) *Unwashed milkers' hands* (Fig. Ce 2). Water used for washing may with advantage be treated with a little chlorine disinfectant (2 oz. hypochlorite per 3 gal. water) to prevent the transfer of organisms from one animal to another and to keep down bacterial growth generally. Never practise " wet hand " milking. If milking machines are used, be particularly careful to follow the instructions for cleaning and sterilising.

(4) *Unsterilised pails* and (8) *Unsterilised churns* may be considered together. The weakest link in the chain of milk production is usually the utensils. Bacteria flourish under the conditions present in dirty milk utensils. The first essential therefore is : *Rinse all utensils at the first opportunity. Never let milk dry on.* If emergency conditions prevent sterilisation, clean the utensils thoroughly, rinse several times with tap water and leave to drain in a clean atmosphere. *Cleanliness is the most important aspect of sterility.* Even the application of powerful disinfectants may fail to sterilise utensils if dried-on milk residues are present. This is one of the reasons why the application of steam is preferable. Efficient steaming never fails. On no account leave milk residues about in pails or churns. If a steam-sterilising chest (Fig. Ce 3), is not available, pails and churns should be placed over a powerful steam jet for at least 3 *min.* Alternatively an old-fashioned copper makes an excellent sterilising chest. Don't forget the churn lids.

(5) *Dusty atmosphere.* In hot, dry weather the dust in the atmosphere may become a serious source of contamination. This type of infection may result in *sweet curdling,* a fault accentuated by pasteurisation and therefore of serious economic importance. The presence of bedding, straw, chaff, hay, etc., greatly increases the seeding of the atmosphere with the causative organisms. Therefore, if possible, keep these materials away from the milking shed (Fig. Ce 4), and in any case do not disturb them immediately before or during milking. If the atmosphere is obviously dusty, protect the filter and mouths of churns with a metal cover such as a new clean dustbin lid. *See* Sweet curdling.

(6) *Unsterilised coolers* and (7) *Failure to cool.* Coolers (Fig. Ce 5), unless carefully sterilised and protected, may do more harm than good. Cooling is always advisable, and the milk should be cooled to at least 55° F. (preferably less) *and kept cool.* The temperature is the most important condition affecting

the rate of growth of bacteria as the following table shows :

Temperatures of holding	*Plate count after twenty-four hours*	
	Clean milk	*Dirty milk*
41° F 5° C	2,600	43,000
50° F 10° C	11,600	89,000
55° F 13° C	18,800	187,000
61° F 16° C	180,000	900,000
68° F 20° C	450,000	4,000,000
86° F 30° C	1,400,000,000	14,000,000,000

Note that 55° to 60° F. is the critical temperature for milk deterioration. A poor quality milk will " hold up " if kept below 55° ; a good milk will deteriorate if held at temperatures over 60° F. A point of practical importance is the standing of churns awaiting collection from farms. These often stand on a roadside platform to receive the full effect of the sun. A shade, even if only of three-ply wood or canvas, will do much to prevent the warming up of the churns.

Keeping the night's milk cool in hot weather is the biggest problem of the small producer. When milk is returned, the cause of the trouble is nearly always the night's milk which has been allowed to stand unprotected overnight. Simple expedients are (i) standing churns in a hole in the ground ; (ii) covering with wet sacking, taking care not to contaminate the lip of the churn ; and (iii) standing in a trough of cold water. Obviously these precautions are only necessary during hot nights. As an indication we may say that when the atmospheric shade temperature at 7 p.m. is 70° F. or higher, these precautions should *always* be taken. If the cooling water is above 60° F., satisfactory cooling cannot be achieved, and these precautions should then be adopted throughout the summer months. Leaky coolers are a great source of trouble in hot weather and are frequently the cause of adulteration and *ropy milk* (*q.v.*). *See* Cooling.

(8) *See* under (4).

(9) *Unsterilised storage tanks.* The sterilisation of storage tanks is always a problem. The best way is to clean first with a good detergent, using stiff brushes, thoroughly rinse out with good tap water and then " steam out " for 1 hr., covering any apertures with a metal lid.

Alternatively tanks may be sprayed with chlorine solutions.

(10) *Recontamination after pasteurisation.* No care can be too great to prevent this. Recontamination is the commonest cause of the presence of *B. coli* in pasteurised milk. A point often not realised is the tremendous effect of a little bad milk on a bulk of good milk. Thus the addition of only 0·1 per cent. of filthy milk having a count of 1,000,000,000 (such as may easily be present in certain parts of dairy plant) to clean milk will raise the count by 1,000,000. Moreover, these bacteria will be actively growing and ready to " shoot-off " in a new milk. *See* Cleaning and sterilising.

(11) *Unsterilised bottling plant* and (12) *Unsterilised bottles.* Fillers should always be dismantled immediately after a run and all parts thoroughly rinsed, washed, and sterilised. It is immaterial whether steam or chlorine is used for sterilisation, provided the job is done properly. Sterilisation immediately before use is advantageous and the first few bottles of milk should always be discarded.

The commonest faults in bottle washing are : (1) Failure to treat bad-condition bottles separately ; (2) weakening of detergent ; (3) too low a temperature in detergent tank ; (4) contamination of rinse sections ; (5) inefficient jets. *See* **Bottle washing.**

(13) *Holding bottled milk at high temperatures* (*over* 60° F.). Bottled milk is normally held in a cold store (40° F.) until sent out for delivery. It is unfortunate that cold stores become less cold in hot weather, a common temperature being 50° F. or thereabouts. Further, bottles in crates may take 8 hr. or more to attain the cool temperature of the store. A combination of these factors and an unshaded van may have alarming results. The domestic refrigeration of milk is still the exception in this country. It is essential, therefore, that the retailer should do all he can to deliver the milk at the lowest possible temperature to the consumer.

Filtration of Milk. It should be emphasised that filtering only removes *visible* dirt, which of itself does not affect keeping quality. Bacteria are far too small to be retained by filter cloths (Fig. Ce 6). These may retain straw, dust, etc., but any bacteria originally on these will have been mostly washed into the milk.

Refs.: Hill (1952), *Clean Milk*, London; Min. Agric (1937), Bull. 52, *Modern Milk Production*, H.M.S.O.; Orr (1915), *Pub. Hlth.*, **28**, 208; McKenzie *et al.* (1950), *SAB*, **13**, 19.

CLEAN MILK PRODUCTION—THE RELATIVE IMPORTANCE OF VARIOUS FACTORS. This subject is a never-ending source of discussion for dairy farmers and advisers but it is generally accepted now that sterile utensils and adequate cooling are the predominant factors. Since all factors must be quantitatively defined it is obviously impossible to be dogmatic on the subject.

The results of a recent investigation are shown in Table CM I (Davis *et al.* (1945), *SAB*, p. 69). *See* Abnormal milk; Bacteriological grading; Bottle washing; Chlorine; Churn washing; Cleaning and sterilising; Cooling; Detergents; Mastitis; Pasteurisation, in bottle.

Refs.: Enock; Hammer; Min. Agric. (1937), *Studies Concerning the Handling of Milk*, Bull. 31, H.M.S.O.; Ben Davies (1933), *The Nation's Milk Supply*, London; Mattick (1927), *The Production and Distribution of Clean Milk*, London.

CLEANING AND STERILISING OF DAIRY PLANT. Any attempt to describe methods of cleaning and sterilising dairy plant which are both accurate and precise is doomed to failure, as both operations are not only governed by a knowledge of certain scientific principles, but each in itself is an art which can only be developed by practice and experience.

It is generally agreed that cleaning and sterilising are fundamentally two different operations when used in connection with dairy plant and that cleaning must precede sterilisation. Accordingly the two processes will be dealt with separately.

CLEANING. The cleaning of dairy plant is carried out in three stages; (*a*) *Rinsing*—the purpose of which is to remove loosely held milky residues and which can be regarded as a preliminary operation. (*b*) *Scrubbing*. This is usually a manual operation, the purpose of which is to free equipment from adherent matter. (*c*) *Rinsing*. The final process, the purpose of which is to remove all traces of residue.

Before proceeding to the purely practical aspects the following points may be considered.

Water supply. It is desirable that the water supply should be soft. Where hardness is appreciable, it is recommended that softening plant of adequate capacity should be installed.

Steam supply. The steam supply should be free from solid and gaseous impurities and available at sufficient pressure. The supply should be neither too wet nor too dry and to guard against accidents, fixed or flexible metal piping should be used wherever possible.

Detergents. In brief, the detergents used for the purpose of washing plant should have good solvent properties and chemical reactions between solution and residues should be such that the latter are either taken up into solution or maintained in a state of suspension, even when the solution is at low temperature.

TABLE CM I

THE EFFECT OF DIFFERENT FACTORS ON K Q. IN ORDER OF IMPORTANCE *

Code No. of pair of treatments	*Pairs of treatments*		*No. of trials*	*No. of trials*					*Classification*
				In favour of (a)			*In favour of (b)*		
	(a) Experimental	*(b) Control*		*Marked*	*Slight*	*No difference*	*Slight*	*Marked*	
1. . .	Use of surface cooler	Not cooling	6	6	0	0	0	0	Very significant
2. . .	Utensils steam sterilised	Utensils only drained of milk	4	4	0	0	0	0	
3. . .	Utensils steam sterilised	Utensils only washed	5	4	1	0	0	0	
4. . .	Utensils sterilised with hypochlorite †	Utensils only drained of milk	5	3	2	0	0	0	
5. . .	Utensils sterilised with hypochlorite †	Utensils only washed	8	5	1	1	1	0	
6. . .	Trough cooling	Milk uncooled	9	3	3	3	0	0	Significant
7. and 8. .	Dry-handed milking	Wet-handed milking	7	3	1	1	2	0	
	Straining through sterilised strainer	Milk unstrained	6	2	1	2	1	0	
9. . .	Washing udders ‡ (hypochlorite solution)	Udders unwashed	7	1	4	0	2	0	Slight or variable
10. . .	Rejection of foremilk	Inclusion of foremilk	4	0	1	0	3	0	Negligible
11. . .	Washing hands ‡ (hypochlorite) between cows	Hands unwashed between cows	8	1	4	1	1	1	Negligible or variable
12. . .	Milk unstrained	Use of unwashed strainer	9	2	1	0	2	4	Variable
13. . .	Milk uncooled	Use of unwashed cooler	8	4	1	1	0	2	
14. . .	Utensils sterilised with hypochlorite	Utensils steam sterilised	7	1	2	1	1	2	

* The better treatment is listed first in pairs 1-9. ‡ 800 p.p.m. chlorine.

† Utensils sterilised with solution at 160-180° F. containing 320 p.p.m. chlorine and rinsed with water containing 40 p.p.m.

Suspended matter such as butter fat globules or fragments of denatured or coagulated proteins should show a minimum tendency to coalescence and/or precipitation.

It is further suggested that detergent mixtures might have incorporated in them some substance or substances which are present primarily on account of their lethal effect. If such substances also have detergent properties so much the better. It should, however, be borne in mind, that strong alkalis are unsuitable as the conditions and circumstances of usage of plant-washing mixtures are quite different from those used for bottle-washing purposes. Moreover, substances of the phenol group must not be used on account of their odour and possible effect on the phosphatase test.

Proprietary detergents used for plant-washing purposes vary considerably in composition. They are usually a mixture of the salts of the alkali metals, such as caustic soda, sodium carbonate, trisodium phosphate, and sodium silicates (ortho, meta, and sesqui salts) and may also contain organic wetting agents, colloids such as starch, water softening salts such as sodium hexametaphosphate, and abrasives such as fine sand, Fuller's Earth, etc. As the composition of these proprietary mixtures is not usually specified by the manufacturers, the dairy manager must rely on the integrity of his suppliers to provide him with suitable materials at economic prices. The following points are, however, perhaps worthy of brief mention—fuller details appear elsewhere.

(*a*) Caustic soda is seldom incorporated in plant-washing mixtures. It has poor rinsing qualities and a very harmful effect on the human skin, even when used in dilute solution. Its marked germicidal and solvent action on milk solids, together with its lubricating properties on the other hand make it a most desirable constituent of a detergent for bottle-washing purposes.

(*b*) The corrosive action of detergents is becoming of less importance as more and more plant is being fabricated of stainless steel, but there are nevertheless many dairy utensils made of aluminium or aluminium alloys and tinned steel or tinned copper. These metals are most susceptible to attack, and to minimise damage, mixtures used should contain inhibitors such as sodium sulphite or sodium chromate (for tinned materials) or contain a high proportion of silicates (for aluminium).

(*c*) The incorporation of sodium hexametaphosphate or tetra-sodium pyrophosphate in plant-washing mixtures has been found advantageous in certain instances where the water supply is " hard ". The soluble calcium and magnesium complexes formed in solution reduce the troublesome deposits formed on utensils and which can often only be removed by the use of abrasives.

(*d*) The use of abrasives, either in the form of steel or wire wool or in powder form, is to be deprecated for plant-cleaning purposes. Suitably balanced mixtures should provide for all conditions encountered in commercial practice.

General Facilities. Equipment used for plant washing is just as important as the plant itself.

Washing troughs, sufficient in number and of ample capacity, conveniently situated and suitably illuminated, by daylight and artificial light, are absolutely essential. Troughs such as those shown in Fig. Cle 1 are admirable for pipe lines, etc. These should be of length sufficient to accommodate pipe line runs of 10 ft., and fitted with tripod legs with adjustable feet for ease of levelling and have overflow holes arranged at the top. They should be made of heavy gauge metal, galvanised and of generally strong construction. The troughs are usually arranged in pairs, the reason for which will be given later.

For smaller pieces of equipment such as valves, T-pieces, jointing rubbers, etc., twin sinks, as shown in Fig. Cle 2 have been found satisfactory. The capacity of each sink is approximately 3 to 4 gal. The draining boards on either side consist of rubber sheeting $\frac{1}{2}$ in. thick, resting on a galvanised iron framework.

The usual 2 to 3 gal pail and the usual type of mop bucket are most useful accessories for washing down fixed equipment, i e filler bowls, heating and cooling equipment, etc

Brushes used for plant cleaning should not be too hard as they might cause abrasion They should be used to remove adherent material which has already been softened by detergent solution Used as abrasives, they have a short life and plant surfaces once scratched become more and more difficult to clean For the storage of brushes and other general equipment cupboards such as those shown in Fig Cle 3 have been found useful The open wire mesh sides and shelves facilitate draining and drying

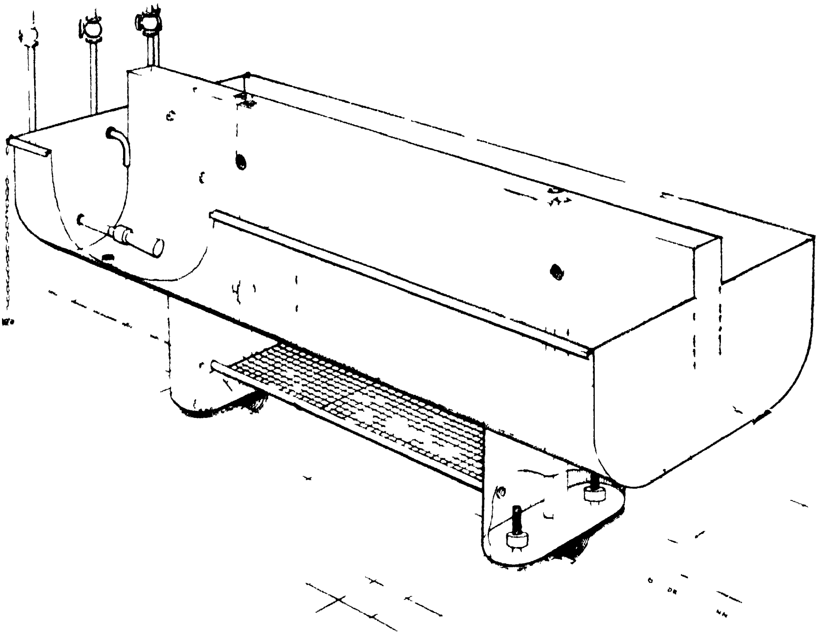


FIG Cle 1 —*Washing Trough for Milk Pipes, etc*

Note —Levelling screws at base and overflow holes

Personnel. The question of personnel is important and the selection of staff should be done most carefully. Efficiency can only be achieved by the thoroughness and conscientious spirit of the individuals whose work it is; materials are secondary. Hence, the general conditions of employment should be conducive to good work. Staff should be taught the principles and practice of cleaning and should receive written instructions on procedure, and methods should be demonstrated.

Cleaning and sterilising staff, in common with other staff, invariably show a greater interest in their work when they are shown the bacteriological results obtained. Especially is this the case where plant swabbings are taken and tested systematically. The bacteriological results obtained can be of inestimable value both for demonstration purposes and as a basis for bonus payments.

Practical considerations. The milky residues left on plant surfaces at the termination of processing operations show considerable variation both in nature and amount, and for practical purposes can be described as follows: (*a*) Those

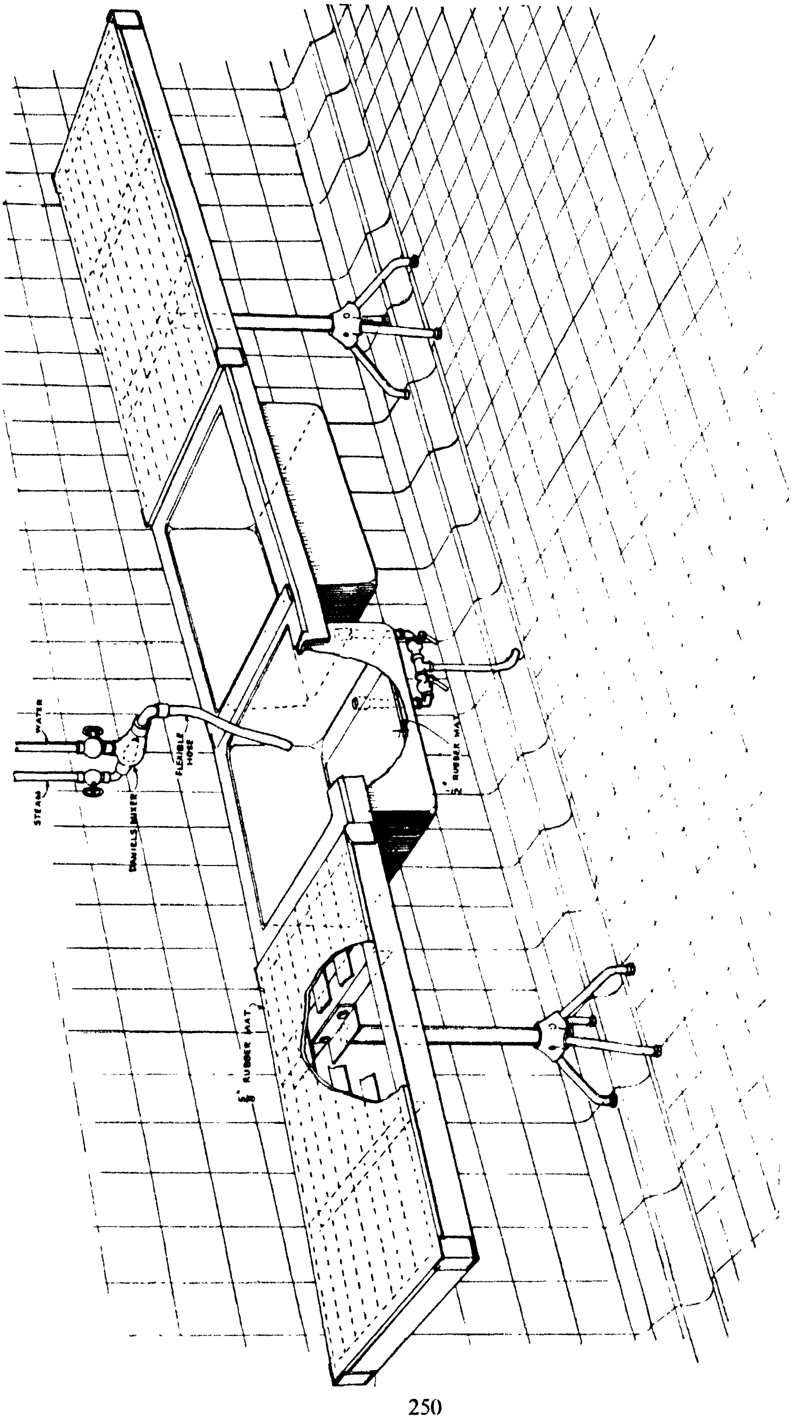


FIG. Cle 2.—*Twin Sink Assembly for Washing Valves and other Small Fittings.*

formed by contact with cold or slightly warm milk. (*b*) Those formed or deposited by hot milk.

Type (*a*) will occur in equipment such as rail or road tanks, cold milk storage vessels, tipping and weighing tanks, precoolers and surface cold milk coolers, certain pipe lines, bottle-filling and churn-filling machines, cold milk float tanks, and certain sections or parts of pasteurising equipment, *e.g.* early stages in regeneration, cooling sections, etc.

Type (*b*) will occur chiefly in milk treatment plant, pasteurising, and heating equipment generally.

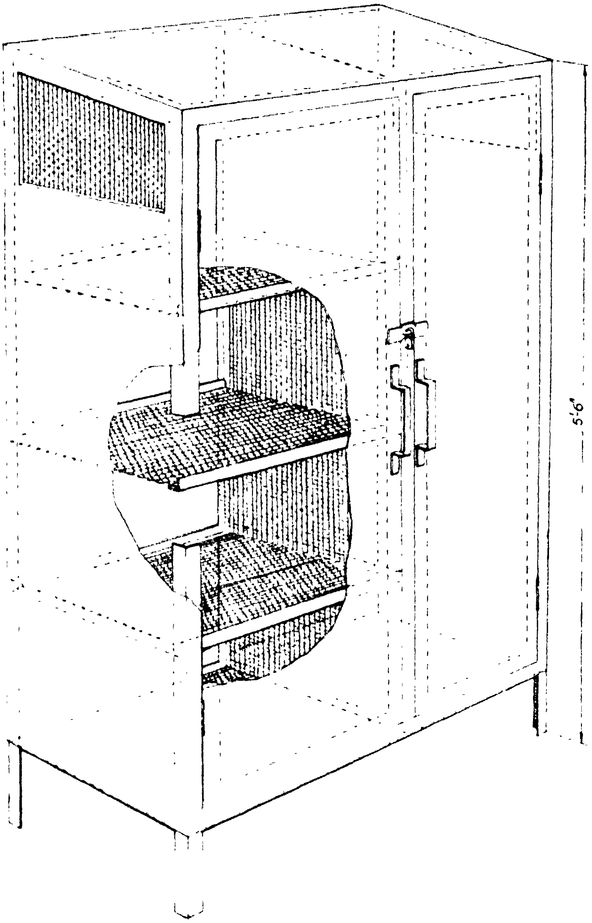


FIG. Cle 3.—*Storage Cabinet for Brushes, Pails, and General Cleaning Materials, etc.*

Rinsing. The preliminary rinsing procedure is applicable to all types of equipment. It consists of circulating or hosing plant with cool or cold clear water, and should begin immediately processing is finished. In the case of heat exchangers there should be no interruption between termination of the milk and the commencement of the water flow. Heating should, of course, be discontinued immediately the milk flow ceases. Cooling of the plant may be assisted by turning on the cold water supply on the heating side. The water flow on both sides of the plant, *i.e.* the heating section and corresponding milk section should continue until the plant itself feels quite cool and no traces of milk are apparent in the outflow. Whilst this is proceeding the brine or cooling medium should be released from the cooling section of the plant and returned to the evaporator tank. As the rinsing operation is being completed all pipes and wherever possible other joints (with the exception of heating plant) should be slackened off so that they will leak freely. Finally, the water supply is turned off and all pre- and post-heat treatment sections of the plant completely dismantled. Pipe lines and other long pieces of equipment are then immersed in the washing troughs in detergent solution.

Rubber jointing rings, filler air tubes, milk cocks, and other small parts are laid out on one of the draining boards of one of the twin sinks.

Scrubbing. Scrubbing is a manual operation, removal of residue being accomplished by means of suitable brushes and assisted by the use of a suitable detergent solution. The strengths of these detergent solutions for the various purposes will be supplied by the manufacturers of the products used. As a general rule solutions used for hand washing purposes are ordinarily ¼ to ½ per cent. by weight (¼ to ½ lb. detergent per 10 gal. water) but for circulating purposes slightly higher strengths are generally used, ½ to 1 or even 2 per cent. by weight (½ to 1 lb. or 2 lb. per 10 gal. water).

In the case of fixed equipment such as filler bowls, surface cold milk coolers, etc., a warm solution (not exceeding 110° F.) is brushed over the milk-bearing surfaces. Higher temperatures than this are not recommended as there is a possibility of the solution drying and leaving a " bloom " or skin of silicates, etc., which can only be removed by the use of abrasives. After scrubbing the equipment should be rinsed thoroughly.

The method of washing road and rail tanks and cold milk storage tanks is essentially similar to the above. The warm solution is brushed over the surface, this being followed by rinsing.

The practice of closing outlet cocks on milk tanks, tipping tanks and on filler bowls, then making up and using a detergent solution contained in the vessel is not very satisfactory, as the solution very soon becomes cold and ineffective.

Detergent solution can be prepared in large pails, placed in an accessible position and Turks head and other brushes dipped into the solution as required. Solutions should be renewed frequently. This procedure will generally be found satisfactory but in larger dairies it will usually be found economical to use detergent solution under pressure for washing purposes, pressure being controlled by the pistol type valve in the hands of the operator.

Pipe lines and other parts immersed in the troughs can be dealt with as follows :

The detergent solution in the trough, together with pipes, etc., immersed in it is warmed up to approximately 160° F. by direct steam injection. The steam supply is then turned off and the trough and contents allowed to cool. If in 20 to 30 min. the temperature has not fallen to 110° F. or so, the cold water supply is turned on, the solution being allowed to overflow through the outlet holes provided at the top of the trough. Allowance for loss of strength of the solution in the cooling process should be made by trial and error methods, the working strength aimed at being ¼ per cent. by weight.

Dilution should not be allowed to proceed until all the detergent has been run to waste. Solutions of such strengths (¼ per cent.) should cause little discomfort to the hands of the operatives, moreover, the temperature will be insufficiently high to permit drying on of milk and detergent residues. Each piece of equipment is then thoroughly brushed internally and externally, dipped in the solution, then transferred to the second and similar trough placed alongside—this trough being previously filled with cold water and allowed to overflow throughout the process of washing—then the water supply is shut off, outlets opened and allowed to drain. Subsequently it is refilled with cold water and hypochlorite solution added to give a concentration of 50 to 100 p.p.m. By this means the equipment contained in the trough receives partial, though perhaps incomplete, sterilisation before being assembled.

A similar method of treatment is recommended for the numerous small and odd parts of equipment which are placed on one side of the draining boards of the twin sinks. In the case of milk cocks, which are liable to be damaged by careless handling, each part should be brushed with solution then dipped first in the solution, then in cold water in the second sink and immediately reassembled.

Rubber and fibre jointing rings and other removable compressible seals need careful and systematic attention. In view of their composition they absorb butterfat, oil, and water and become not only foul smelling but latent sources of contamination. They should receive treatment similar to that described above, inspection being thorough and replacement frequent. In addition, it is recommended that two complete sets should be in regular use, one set being in actual use, the other set awaiting use. The set not in use can be allowed to remain in hypochlorite solution for say, 4 to 6 hr., then slipped over a rod affixed to the twin sinks to enable them to drain and dry out before being used again.

Heat-exchangers and other equipment which come into contact with hot milk are undoubtedly very difficult to clean and methods of cleaning must take peculiarities of the equipment into consideration.

Tanks or vessels which have either been used for heating milk (*e.g.* batch pasteurisers) or have contained hot milk (*e.g.* hot milk balance tanks and holders), present a problem which is different, for instance, from heat exchanger units. In the latter, hot detergent solution can be circulated and full advantage made of a pressure system, whereas in the former case only contact and hand brushing is possible.

In the case of heat exchanger units of the enclosed, semi-enclosed, or open types, the following method has been found effective :

After rinsing, the detergent solution is pumped round the system for at least 20 min. For this purpose a special pumping unit is used, as detergent solution will inevitably cause damage to the glands of milk pumps if they are used. Beginning from a cold solution, the solution is heated by direct steam injection until it attains a temperature of approximately 160° to 170° F., the steam is then turned off and the solution allowed to circulate until the temperature has fallen to approximately 100° to 110° F. The time required should be approximately 20 min. to ½ hr. (It is important to note that the heating side of the system should never be utilised to raise the temperature of the solution on the milk side.) At the end of this time the solution can either be released or cool water added to the solution hopper and circulation continued for a short time. Eventually the pressure is taken off the plates or off the manifolds, all joints loosened and allowed to trickle freely for a few minutes, then the power is shut off and the machine completely dismantled. The plates or heater tubes, etc., are afterwards brushed with a mild detergent solution, rinsed, and allowed to drain before reassembling. Care should be taken if the heating side of the system is used to raise the temperature of the solution on the milk side.

The treatment of batch pasteurisers, hot milk tanks, holders, etc., is very similar. Where possible, the vessel is filled with detergent solution, heated by steam injection, cooled, diluted with cool water, the solution released, then the apparatus brushed and finally rinsed. Where the capacity of the milk tanks is such that large amounts of solution would be required and difficulty would be experienced in heating and cooling such large bulks, it has been found possible to clean such equipment with detergent solution in the same way as that described under road and rail milk tanks. This method is effective only when the preliminary rinse has been carried out immediately after processing.

An alternative method of cleaning metal surfaces is to prepare a smooth paste of the detergent, spread this over the milk-bearing surfaces, allow a minimum contact time of 10 min. or so, then rub off by brushing with much water and finally rinsing.

Heating equipment of the enclosed type assembled in more than one frame can for the purpose of cleaning be treated in sections, and the treatment of individual sections can be varied according to the nature and the amount of adherent milky residue on them. Also under certain circumstances, *e.g.* in cases of unduly long processing runs or where the run has been interrupted many times, it will be found advantageous to circulate detergent solution twice instead of once. Different strengths of solution and different temperatures may also be employed, depending on these circumstances. In any case, cooling and rinsing between circulations is advisable if good results are to be obtained.

Reference should perhaps be made to the wide-spread practice of using acids for cleaning purposes. The acids used in this country are chiefly dilute solutions of phosphoric acid, inhibited hypochloric acid, and nitric acid. In the U.S.A. milder acids are also used, *e.g.* gluconic, tartaric, acetic, etc. These acids, which are circulated previous to the alkaline detergent wash, have been found materially to assist the removal of heat-hardened deposits and milk stone, as it is called. However, few have recommended their use as a routine matter, owing to their corrosive action on metals other than stainless steel. Occasional and careful use may be necessary under exceptional circumstances, but the danger of pitting of joints and bends is so serious that in many well organised dairies their use is entirely prohibited. Similarly, steel or wire wool and other abrasives are forbidden, except for burnishing the exterior of equipment.

Final Rinsing. This process ordinarily follows the loosening of milky residues. It should be thorough and continued until surfaces are free from any residue and until all traces of the detergent solution have been removed.

Conclusion. Success in cleaning methods can be assessed not only by visual inspection, but also by carrying out swab tests. Visual inspection can be carried out when the plant is either wet or dry. Apart from carefully examining milk cocks, agitator bearings, blank ends, ring joints, seatings, etc., or the usually neglected points (this should be unnecessary if a good procedure is adopted), surfaces should be rubbed over with a piece of clean absorbent material, *e.g.* filter cloth, cotton wool. Dirty smudges on the material point to inadequate or unsuitable methods and the presence of alkali to inadequate rinsing.

Where equipment has either been allowed to dry or dried by means of a steam jet, examination of surfaces will reveal the presence or absence of " bloom ". In addition, any scratches or pitting will be apparent ; these may be due to the use of an abrasive or the choice of an unsuitable detergent. A small piece of mirror held close to the surface or a lens will be found helpful when making such inspections.

Swabbing of plant previous to sterilisation can also be of value, but at the present time it is little used. Bacteriological results should approximate to those of the water supply if cleaning methods are satisfactory. The presence of coliform organisms, excessive numbers of bacteria, thermoduric and thermophilic organisms, and sporing bacteria (tested by laboratory pasteurisation of swab rinses) are evidence that cleaning methods are at fault, assuming, of course, that the water supply is good bacteriologically.

Under closely controlled conditions, sterilisation should be a safety measure carried out as a matter of routine, and until plant cleaning is considered to be a work of equal or even more importance than processing itself reliance will inevitably be placed on sterilisation to achieve any measure of plant sterility.

STERILISATION OF DAIRY PLANT. The principle of sterilisation of dairy plant is almost elementary, but practical methods of achieving sterility of plant surfaces are often unnecessarily complicated and inefficient. Instead of achieving absolute sterility, swab tests often reveal the presence of excessive numbers of micro-organisms and frequently contaminants of the coliform group, thereby indicating either the need for more thorough treatment or modification of machine design or construction to enable sterilisation to be a practical possibility. With care, however, modern plant of reputable make can be efficiently sterilised and extremely good and consistent bacteriological results can be obtained, provided at least equal care has been exercised during the preceding cleaning process, which for practical purposes should be regarded as the first stage in the process of sterilisation. A well cleaned surface is comparatively easy to sterilise, an unclean surface difficult and sometimes impossible using ordinarily efficient methods.

An opinion is sometimes expressed that a special process of sterilisation is by no means essential in dairy operations. Such a contention is not always easy to disprove, but in many cases it will be found that cleaning methods are usually so thorough and plant has been maintained in such excellent condition that the process of cleaning in itself has also combined that of sterilisation. Other apparent exceptions might also be quoted, but, in general, a definite process of sterilisation is necessary at every stage in the chain between producer and consumer if contamination is to be reduced to the absolute minimum.

Principles of Sterilisation. Sterilisation depends mainly on three factors: (1) Intensity of the sterilising agent. (2) Duration of effect. (3) Sequence of treatments.

Before consideration is given to these three interdependent factors, it is necessary to give some indication of the practical difficulties.

The question of sterilisation is intimately related to that of the conditions of the plant surfaces and the surface films which are contaminated. Irrespective of the nature of the metal or the composition of the material, a smooth surface is undoubtedly much easier to sterilise than one which is either rough or pitted. If, however, a smooth surface is patchily or evenly coated with milk or detergent residues, it will be found troublesome to deal with, and although such surfaces can be sterilised the methods employed will need to be much more drastic than would be necessary were they thoroughly clean.

Efficient sterilisation is invariably facilitated if surfaces are perfectly smooth and either moist or wet. In this condition the micro-organisms will tend to be in a state of suspension and the germicide can be expected to exercise its maximum lethal effect.

The following is a short description of the difficulties and limitations of some of the various methods of sterilisation used commercially.

Steam and hot water methods of sterilisation depend for their effect upon the heat developed and duration of heating. Methods which rely on heat must be expected to be wasteful, as only a small proportion of the total heat is actually used. Much heat is dissipated or expended in heating the equipment to a sufficiently high temperature to enable the heat developed to be germicidal.

The economic and practical difficulties in dealing with large items of equipment, *e.g.* tanks or large masses of metal in heat exchangers, etc., by such methods will be obvious, but such considerations are very frequently more than outweighed by the excellence of the results obtained. Not only is the process of sterilisation by steam or hot water brought about by heat alone but by a combination of heat and rinsing by condensate or the use of large volumes of water. In the case of coolers containing comparatively large amounts of refrigerant the heating effect is often negligible, and it must be assumed that sterilisation is accomplished by the rinsing effect with sterile or nearly sterile water.

The chief advantage of using heat as a means of sterilisation is that it is very penetrating, and imperfections of surfaces such as roughness or pitting or presence of butterfat or other residues are of little consequence, provided the temperature attained is sufficiently high and the period of application long enough.

Great care must be exercised if the advantages are not to be outweighed by the disadvantages of comparatively high cost and possible damage to equipment which is liable to occur when certain items of plant, such as heat exchangers, bottle-filling machine bowls, coolers with fixed headers, etc., are subjected to the repeated strains and stresses induced when they are heated to the unusually high temperatures necessary for effective treatment.

In the case of hypochlorite solutions, the physical protection of contaminants by butterfat globules and surface deposits is a more serious matter and perhaps the chief reason for chlorination methods often being regarded as ineffective. It should, therefore, be noted carefully that satisfactory results can be achieved only if intimate contact is established between germicidal solution and micro-organisms. The presence of solid matter, either as detached residue or as a film not only serves as a barrier and prevents germicidal action but also decreases available strength owing to chemical action, surface adsorption and similar effects.

Efficient sterilisation by means of hypochlorite solution as with heat depends upon intensity and duration. Intensity in this instance is assessed in terms of available chlorine in solution and for practical purposes concentration of chlorine and contact time are usually regarded as complementary, *i.e.* high concentrations require relatively short contact times, low concentrations correspondingly longer contact times to produce similar effects. The upper limit of concentration used on a commercial scale is of the order of 250 to 300 p.p.m., exposure time at this strength being not less than 1 min. but usually not longer than 5 min. The use of such relatively strong solutions is not recommended. Solutions containing 50 p.p.m. available chlorine allowed to act for a minimum period of 5 to 10 min. are usually quite as effective as stronger solutions and the danger due to corrosion appreciably less.

Practical Considerations. (1) ***Steam and hot water methods of sterilisation.*** Steam or hot water methods of sterilisation should aim at attaining surface temperatures of more than 170° F. (82° C.) and maintaining this temperature for a minimum period of 25 to 30 min. If higher temperatures (*i.e.* temperatures exceeding 200° F.) can be obtained the time may be reduced to some extent but never to less than 15 min. Where possible, the plant should be loosely assembled so that all joints " weep " or leak slightly before the process of sterilisation. If steam is used special inlet fittings of the type shown (Fig. Cle 4) will be found useful—they permit a constant flow of steam and allow for forcible expulsion of the condensate which accumulates in the plant. Wherever possible, these

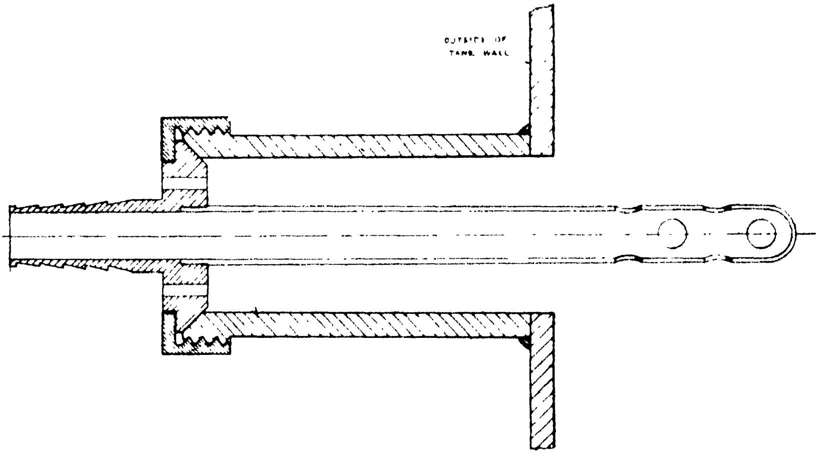


FIG. Cle 4.—*Steam Sterilising Device.*

Note.—Projecting pipe can be unscrewed and other types substituted.

steam inlets should be provided at the lowest possible points as the tendency is for heat and water vapour to rise and this will ensure uniform rather than localised heating to take place. They should also be provided in sufficient number so that the effect of pressure reduction and possible resistance to steam flow will not necessitate unduly long periods of time to elapse before sterilisation is taking place at the most distant points from the inlets.

Steam gauge pressures higher than 45 to 50 lb. per sq. in. are unnecessary and usually wasteful of steam. On equipment attaining sterilising heat the steam supply can usually be reduced, as it is only necessary to maintain the heat already developed in the system.

The manner of usage of hot water for sterilising purposes is rather different from that of steam. Two methods are commonly used. The first employs relatively large volumes of water and consists of filling up a receiving tank with hot water and circulating it round the system eventually releasing it to other parts of the plant, such as filling machines, etc., from where it is run to waste. This method of sterilisation is very effective for pasteurising plants of the semi-enclosed or totally enclosed types, as heating can be accelerated in the early stages and maintained in the later stages by using the hot water circulation system used for milk treatment. This procedure is, however, difficult to adopt for the sterilisation of large storage tanks and road tanks, as it requires the use of such large volumes of water and such long periods must be allowed to elapse before use in order to allow them to cool. This is especially the case when tanks are insulated.

An alternative method is to spray tanks with very hot water in much the same manner as that described later under chlorination. Spraying should be unhurried and aim at minimum surface temperatures of 170 F. being reached. Both these methods of tank sterilisation are capable of yielding excellent results, especially the former, as the latter is liable to much variation at the hands of the operative. Using either of these methods cooling can be facilitated by spraying with cold bacteriologically "clean" or weakly chlorinated water (7 to 10 p.p.m.).

The above methods are easily capable of modification to suit the needs of most dairy equipment. If preferred the smaller units such as pipe lines, etc., can be sterilised under pressure in suitable cabinets, the larger and fixed units being treated by one or other of the methods described. If such methods are used operatives should be informed that careless handling of sterilised equipment during assembling, etc., will give rise to contamination and nullify the previous treatment. Sterilisation when completely assembled is generally more satisfactory and is therefore recommended.

This same possibility of contamination can, of course, be caused by either non- or incomplete sterilisation of the various blanks removed for fitting steam inlets. These should either be pressure sterilised in small cabinets or suspended in wire baskets in storage tanks when they are being sterilised to ensure adequate treatment. They should be replaced loosely whilst still hot immediately the steam inlets are disconnected.

The sterilisation of rubber jointing rings, filling valve rubbers, and other packing materials by means of steam or hot water is feasible but offers practical difficulties. They can either be steamed or submerged in hot water for periods of 20 to 30 min. or longer. Such methods of treatment are not always effective, and have the disadvantage that replacements are frequent. An alternative method is described ater.

(2) ***Sterilisation by means of hypochlorite solutions.*** Several proprietary solutions of sodium hypochlorite have been officially approved by the Ministry of Health and are available for the purpose of sterilisation of dairy plant. As marketed these solutions contain 10 to 12 per cent. available chlorine, but they are always diluted prior to use. Strengths such as 250 p.p.m. are easily prepared

by diluting approximately 400 times, *e.g.* 1 pint solution in 400 pints or 50 gal. of water. For the purpose of plant sterilisation, solutions containing 50 to 300 p.p.m. are generally used. After suitable contact time, such solutions are usually followed with a milder solution wash containing 7 to 15 p.p.m. in order to remove traces of the original solution. The object of this rinse is to prevent the deleterious effects which might accrue from unduly long contact time between solution and metal surfaces and also guard against the possibility of milk taint.

The methods of treatment of plant vary according to the nature and design of equipment, but again it should be emphasised that the aim of chlorination is to bring the solution into actual contact with the micro-organisms.

Two methods of application are in general use. The first method can be used on such items of equipment as pipe lines, pumps, heating and cooling equipment, filling machines, etc. A relatively large volume of water containing chlorine in a concentration of 250 to 300 p.p.m. is circulated round the plant eventually being discharged to the filling machines and then to waste. Previous to circulation it is advisable to spray the loose covers and protecting plates which ordinarily will not come into contact with the milk with a similar solution. These surfaces if sterilised will not be liable to serve as a means of contaminating those milk splashes and droplets of water of condensation which so frequently accumulate and then by some means find their way into the milk stream during processing operations.

Large surfaces such as storage tanks, road and rail tanks are usually sterilised by means of spraying. Spraying should be carried out starting from the lowest and working upwards to the highest points. This tends to give a better " spread " of solution and consequently extends the contact time. A fine spray is to be preferred to a mist or coarse spray. In practice it is found that a minimum quantity of 15 gal. of solution is required to spray a tank of 3000 gal. capacity, using a flow of 1 gal. of solution per min., the spray having an effective area 4 to 6 ft. diameter. Nozzle pressures of 70 to 80 lb. per sq. in. having a " throw " of 6 to 8 ft. are necessary to enable this to be done.

As the melting point of butterfat is lower than 120° to 130° F., it can be expected that the use of solutions within this range of temperature would have a more marked lethal effect. This may be due to two factors: (*a*) Emulsification of butterfat being accelerated. (*b*) The globules of butterfat becoming labile and suspended in the solution thus permitting more intimate contact between germicide and plant surfaces.

Loss of strength of strong or diluted hypochlorite solutions depends mainly on the conditions of storage. Solutions should be kept in stoppered bottles or carboys, stored in a cool place, protected from strong sunlight and kept in stock for as short a time as possible.

Chlorination methods are of special value for rubber jointing rings and other compressible packings. Such materials are best sterilised after cleaning by allowing them to remain in hypochlorite solution containing 50 to 100 p.p.m. chlorine for extended periods, hours if possible. Alternatively, the solution in which they are immersed is warmed to approximately 130° F. and after 5 min. or so contact time they are removed and allowed to dry. When being placed in position on the machines, the operator is advised to dip his hands frequently in a solution of 250 to 300 p.p.m. strength in order to reduce the possibility of contamination.

Finally, after sterilisation, all plant should be rinsed with water containing 10 to 15 p.p.m. chlorine either by circulation or spray methods. This last treatment, carried out as soon as possible after the sterilisation with stronger hypochlorite solutions, will lessen the possibility of corrosion and taint in the first batch of milk processed.

As a means of ensuring sterility in bottle washing, chlorination methods are of some particular interest. In some cases, it is the practice to rely on a final rinse with water containing a low concentration of chlorine—up to approximately 20 p.p.m., in others the first and second rinse tanks and jettings are automatically dosed according to the speed and output of the machine. Under average conditions it has been found that dosage of rinse water (excepting perhaps final rinse) is by no means necessary to ensure bacteriologically satisfactory bottles and that if it is carried out without due care, much damage can be caused to pumps and moving and stationary parts. Systematic cleaning of tanks and spray tubes followed by a single dosage just before the washing process, with subsequent treatments at intervals during the processing run, has been found to give excellent results unsurpassed even by constant dosage throughout. The expedient of constant and systematic dosage either by drip feed methods or by automatic means is often only adopted to cover up inadequate or inefficient methods of cleaning.

RECENT DEVELOPMENTS. Remarkable advances have been made in the technique of cleansing and sterilising dairy plant *in situ*. To some extent the line of development has followed recent American practice. Compared with hand methods of cleaning these improvements are considered labour-saving, more economical in cleaning materials and more efficient from a bacteriological point of view. These comparatively new techniques include the following:—

1. ***In-place Cleaning.*** This is generally applied to pipe lines. The pipe line system is arranged on the ring main principle and may be jointed stainless steel, welded stainless steel or more frequently borosilicate glass. Provision is made for at least one detergent tank and circulating pump. The capacity of the tank or tanks should be equivalent to the capacity of the pipe lines when filled with liquid. If the estimated volume of liquid in the pipe line system amounts to more than say, 200 gal., or where the pump capacity to give a minimum flow rate of 5 ft. per second would develop a pressure exceeding 50 lb. per sq. in. on any pipe line section, it is necessary first to circulate and cleanse only a part of the system and then treat the second section afterwards. Alternatively tanks and pumps can be duplicated and the two sections cleansed simultaneously.

Care should be taken to avoid the use of unlike metals in the circulatory system as this tends to initiate electrolytic action and corrosion. The solution tanks should be thermostatically controlled and provision made for a suitable recording thermometer or accurate direct-reading thermometer. When estimating the capacity of the centrifugal type circulating pump due allowance should be made for friction losses to allow for a minimum flow rate of 5 ft. per second and at the same time guard against excessive pressure development.

It is recommended that raw and pasteurised milk lines be dealt with separately and never linked into a common system. If possible the tanks and circulating pumps should be used specifically on either raw or pasteurised milk lines. This guards against the possibility of high phosphatase readings on pasteurised milk in the event of low temperatures of circulating solution.

The method of cleaning and sterilising is carried out as follows:—

(*a*) The pipe lines are rinsed by pumping cold or luke-warm water through them to waste.

(*b*) A suitably balanced detergent solution is circulated through the system. An alkaline detergent containing polyphosphates and a small percentage of wetting agent is usually chosen for this purpose. The minimum time/temperature conditions for this operation are 145 F. for 35 minutes. At the other end of the scale, it is unusual to exceed a temperature of 170° F. for a maximum period of 15 minutes. The temperatures of solutions should always be checked by a mercury-in-glass thermometer.

(*c*) Without draining the system, rinse with luke-warm water slowly reducing to cold. This can be done by letting luke-warm water into the circulating tank and allowing the return to pass to waste, by changing over to a second rinse tank coupled to the circulating pump, or by direct flow from a calorifier or a steam and water mixer in to the pump delivery line. Rinsing should be continued until the delivery runs clear and is free of alkali, *i.e.* when a sample is not pink to phenolphthalein.

(*d*) Sterilisation can be carried out by circulating hypochlorite or other sterilising solutions, details of which have been described above.

2. ***Semi-Mechanical Cleaning.*** At the present time many of the smaller items of dairy equipment are hand-washed. These items include filler valve assemblies, short connecting pipe lines, milk cocks, etc. A simple means of washing these small units consists of dismantling and placing them separately in trays in a washing tank. A small pump enables the hot detergent solution in the tank to be circulated at moderately high velocity after which rinsing is carried out. These small parts are then subjected to a preliminary sterilisation, re-assembled and finally sterilised *in situ.* This method of treatment is labour-saving and economical in time and materials. It is also very efficient if carried our in a systematic manner.

3. ***Fully Mechanical Cleaning of Rail, Road and Storage Tanks.*** Amongst recent developments is a mechanical device for the cleaning and sterilising of large capacity tanks. Several patterns of spray apparatus are available, but all operate on the same turbine principle. Some are twin or multi-spray heads with the jets set at different angles and rotate in one plane whilst others have a rapidly rotating twin head which moves slowly through 360 degrees. The spray head is fitted with a cover and can either be suspended or fixed in a horizontal plane depending on the position of the manhole in the tank. The washing unit comprises the spray head or attachment, a circulating tank or tanks, and a high pressure centrifugal pump. The latter is usually rated to pass a minimum of 40 gal. of solution per minute at a pressure of 125 to 150 lb. per sq. in.

The normal washing procedure is used as follows: -

(*a*) A preliminary rinse with cold or luke-warm water which is carried out by means of the pump unit or by hosing, and run to waste.

(*b*) High pressure detergent wash with an alkaline detergent solution. This solution may or may not include a sterilising agent.

(*c*) Final rinsing first with luke-warm water, then with cold mains water.

(*d*) Sterilisation with hypochlorite or other sterilising solution.

The time taken to complete this process is less than 30 minutes and it is claimed that the method is much superior in every way to the older system of hand washing.

Conclusion. The sterilisation of dairy plant should not be regarded as a drastic process involving the use of steam at high pressures or strong hypochlorite solutions. As stated previously, it should be considered a safety measure necessary only to prevent or reduce the possibility of contamination. *See* Bottlewashing ; Chlorine ; Clean milk production ; Detergents ; Sterilisation ; Water supplies.

Refs.: Vindal (1949), *IDC*, **4**, 249 ; Davis (1948), *JRSI*, **68**, 547 ; Hucker (1947), 21*st Am. Rep. N.Y. St. Assn. Milk San.*, p. 35 ; McDowall (1942), *N.Z. Dairy Ind. Pub.* No. 136 ; Perry (1948), *J. Milk Food Tech.*, **11**, 88 ; (1947), 21*st Ann. Rep. N.Y. St. Assn. Milk San.*, p. 95 ; Trebler and Harding (1947), *Milk Ind. Found. Conv. Proc.*, **4**, 5.

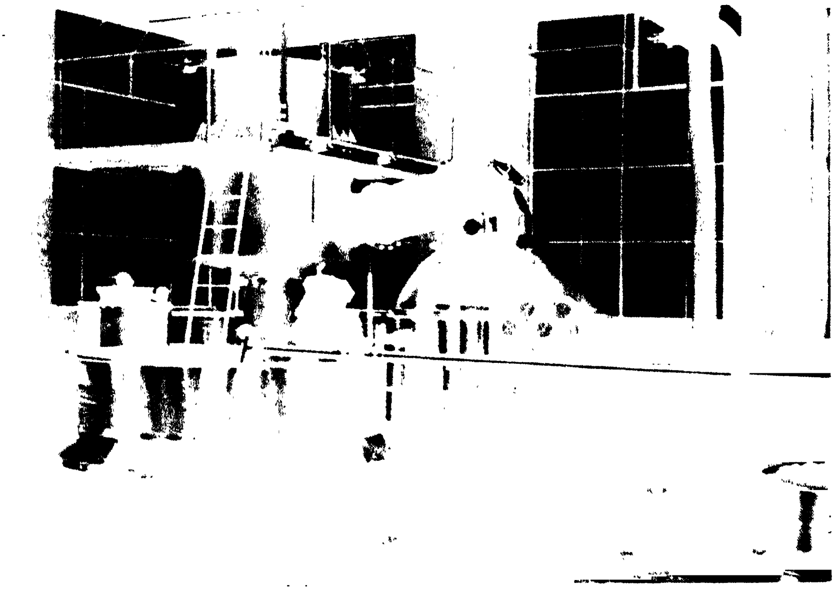
CLOSTRIDIUM. A *genus* of anaerobic spore-forming bacteria which includes the butyric acid bacteria and the organisms of tetanus and putrefaction in meat and other protein material. *See* Butyric acid bacteria ; Cheese ; Classification ; Stability.

Refs.: Bergey ; Wilson and Miles.

CLOT-ON-BOILING TEST (C.O.B.). To make this test 5 ml. of milk are placed in a test-tube in a pot of boiling water for 5 min. and then examined for precipitation. If curd is observed, the milk is said to fail the "clot-on-boiling" test. *See* Bacteriological grading ; Quality payment.

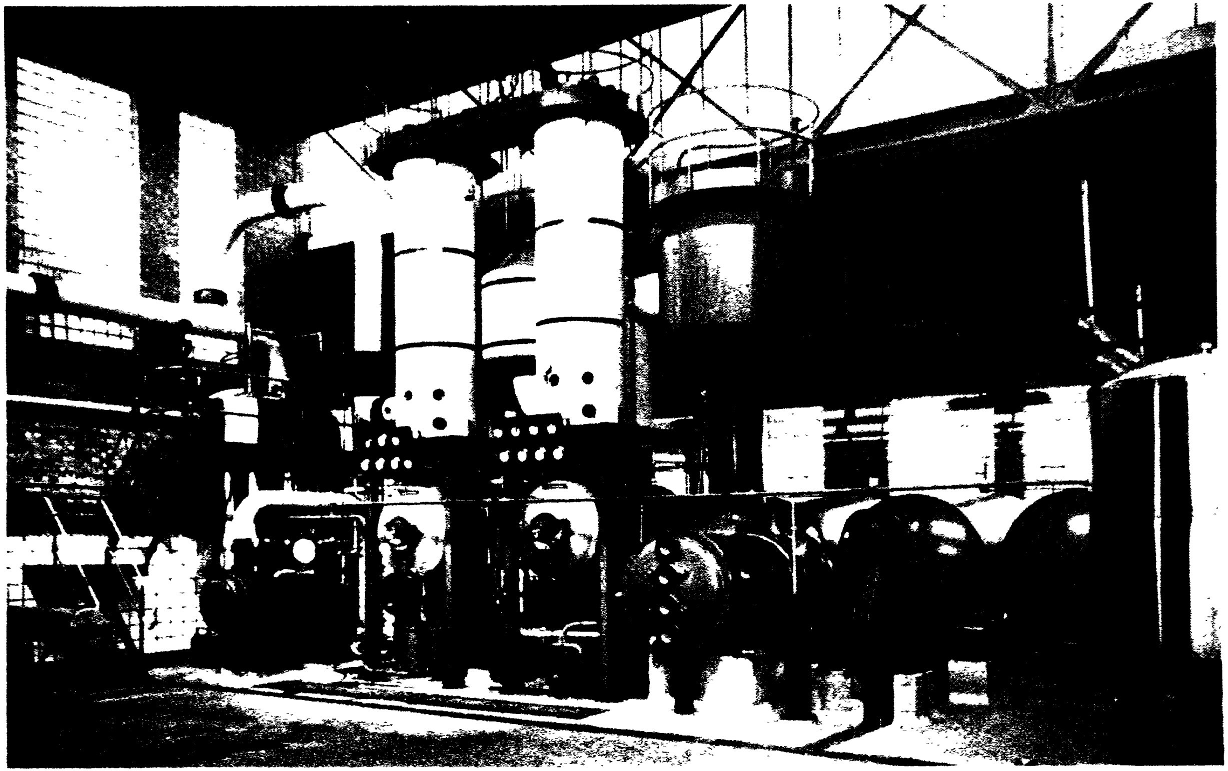
[*By courtesy of United Dairies Ltd.*

FIG. Ce 6.—*The Relative Sizes of Bacteria and the Mesh of Filter Cloths. Cloth* 64 *meshes to the inch Magnified* 75 *times.*



[*By courtesy of Robert Morton Ltd.*

FIG. Co 2.—*Illustration of a " Morton " 6 ft. diameter Staybrite Steel Vacuum Evaporator and Sugar Dissolver.*



[*By courtesy of United Dairies Ltd.*

FIG. Co 3.—*Double Effect Milk Evaporator*, 3000 *gal. per hr.*

CLOT AT ROOM TEMPERATURE TEST. This is made by holding samples of milk at room temperature until they clot. The time required is, on about 90 per cent. of samples, only a few hours greater than the C.O.B. time. Obviously this is controlled by the types of flora present in the sample. It is preferable to hold the samples in an 18° C. water-bath in order to standardise the method. It is then called the clot-at-18° C. test.

CLOTTED CREAM, DEVONSHIRE CREAM. The characteristic body of clotted cream is secured by heating cream or milk of the high-fat breeds in shallow pans to about 180° F. and allowing it to cool slowly. In farmhouses, the pans are heated crudely over a fire or stove and the cream is rich in acid and aroma-producing bacteria. Dairy or factory methods naturally use better controlled methods and steam-heated vats. Souring of clotted cream is due to thermoduric cocci and the characteristic bitter taste is due to various micro-organisms, chiefly of the *B. subtilis*, peptonising cocci and lipolytic *Ps. aeruginosa* (*B. liquefaciens fluorescens*) types (Crossley (1938), *SAB*, p. 5).

Ref.: Sadler (1917), *JDS*, 1, 291.

CLOVER. *See* Feeding; Grass.

CLOVER TAINT. A characteristic taint in milk which may occur if cows feed on a pasture very rich in clover. *See* Flavours; Taints.

CLUMP COUNT. This term is used in the direct microscopic count when clumps of bacteria are counted as single units. When milk or other material is " plated " the single cells can become the nucleus of a bacterial colony, just as large conglomerates which, although they may contain hundreds of cells, only produce one colony in the medium because the bacterial cells are all together. For this reason the clump count usually gives a number which is only slightly higher than the plate count, whereas the Breed or direct microscopic count gives a value which averages about four times the plate count for raw milk, and about eighty times for pasteurised milk. *See* Microscopic count; Plate count.

C.M.D.C. Central Milk Distributive Committee.

COAGULATION. The coagulation or clotting of milk is probably its most characteristic property and is intimately connected with the digestive processes of the suckling of the animal concerned. Thus cow's milk is relatively rich in casein and calcium (the constituents responsible for coagulation by rennet) and is slightly acid (*p*H 6·5 to 6·6) which favours clotting; human milk is relatively poor in casein and calcium and is weakly alkaline (*p*H 7·2). Cow's milk clots in the calf's stomach but human milk does not clot in the same way in the baby's stomach.

There are two distinct types of coagulation: (i) by rennet, either calf rennet or enzymes produced by bacteria (*see* Rennet); (ii) by acid, casein precipitating completely at *p*H 4·6, its isoelectric point (*see* Casein).

The first is largely controlled by temperature, heat-treatment of the milk, and calcium content as well as by acidity; the second is a simpler reaction and appears to be controlled only by the *p*H.

In the absence of rennet milk clots on boiling at a titratable acidity of about 0·23 per cent. " lactic acid " (*see* Acidity), the *p*H being about 6·1. If milk clots at an acidity less than 0·20 per cent., it may be assumed that sweet curdling (p. 1002) is occurring, at least to some extent.

Milk begins to precipitate at room temperature at a *p*H of about 5·1 and an acidity of about 0·6 per cent. Milks may vary appreciably in respect of these standards.

Refs.: Davies; Rogers

COCCUS. A general term applied to all round-shaped (as opposed to rod-shaped) bacteria. It is customary to divide bacteria into cocci, rods, and spirillum or spiral-shaped cells but the last is numerically of very slight importance. Cocci are further divided into diplococci (pairs), tetracocci (fours), sarcinae (packets of 8), streptococci (chains), and staphylococci (grape-like clusters), but systemic names are not necessarily an indication of cell arrangements. *See* Classification.

COCKS. Closures or taps on tanks, tankers and in pipe-lines. Glass pipe-lines normally have stainless steel cocks.

COCONUT CAKE. *See* Feeding.

COD LIVER OIL. This oil is a rich source of vitamins A and D, and so is incorporated in scientifically balanced feeds. Excess lowers the fat content of milk. *See* Composition, factors affecting ; Vitamins.

COFFEE CREAM. A cream of low fat content, *e.g.* 18 per cent., and often homogenised. It is also called single cream. *See* Cream.

Ref.: King (1952), *M*, **7**, 180.

COLD. *See* Clean milk production ; Composition, factors affecting ; Cooling of milk ; Refrigeration.

COLD, EFFECT ON MICRO-ORGANISMS.

Refs.: Mattick (1951), *SAB*, **14**, 211; Davis, 216; Ingram, 243; Proom, 261.

COLD, EFFECT ON MILK. Cold affects milk in the following ways: (i) It enhances keeping quality. (ii) It alters the flora distribution, depressing the acid-producing and encouraging the proteolytic and lipolytic types. (iii) It hastens the solidification of the fat globules (Recknagel effect) and so raises the gravity slightly (apart from the temperature correction). (iv) Frozen milk keeps quite well, but on liquefying it has a slightly sandy feel to the tongue, probably due to the precipitation of calcium salts. *See* Cooling; Psychrophilic bacteria; Refrigeration.

COLI INCUBATION TEST. A method in which a sample of milk is held for *e.g.* 24 hr. at a fixed temperature, *e.g.* 18° C. to allow a certain degree of proliferation of coli before testing. Pasteurised milk should not give coli in more than 1 in 3 tubes for 1 ml. when held for 24 hr. at 18° C.

COLIFORM BACTERIA, " COLIFORMS," * COLI-AEROGENES BACTERIA, ESCHERICHIA—AEROGENES GROUP. Introduction. In this country it is usual to regard the organisms of the group as members of the genus Bacterium, although in America the genera *Escherichia*, *Aerobacter*, and *Klebsiella* are used to divide the group.[1]

Their importance in dairying is due to the fact that their presence in milk and milk products is frequently a reliable indication of faulty methods of production, handling, and plant management. In addition, they are a frequent cause of spoilage in dairy products. As a group, they can be detected by relatively simple techniques, though the isolation and identification of individual species is more difficult.

General. ***Definition.***[2] Gram-negative, non-sporing rods; often motile, with peritrichate flagella. Some species capsulated. Grow well on ordinary media. Aerobic and facultatively anaerobic. All species ferment dextrose with the formation of acid and gas. A wide range of carbohydrates and allied substances is fermented by most species. Occur widely in nature, *e.g.* animal and human intestine, plants, soil, hay, dust, etc.

Morphology.[2] Morphological characteristics are of little, if any, value for the differentiation of species within the group. The cell appears to be without internal structure, stains evenly, and is subject to considerable variation in shape and size. Motility is a characteristic of an individual strain, not species, and non-motile variants frequently occur. Capsules are formed by many species, but this is a variable property often lost on subculture. Many of the strains isolated from milk are capsulated, giving a mucoid growth on solid media. Organisms may be capsulated and motile at the same time.

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* The term " coliforms " is used in this book to mean small, Gram-negative, non-spore-forming rods producing acid and gas in bile salt lactose broth at 37° C. The phrase " coli-aerogenes bacteria " is more accurate but rather cumbersome. The word " coliform " means literally having the form of *Bact. coli.* Bacteriologists use the word " coliform " in different senses ; sometimes the faecal (44° C. positive) types are implied.

[1] Bergey.

[2] Wilson and Miles.

General growth requirements.[2] Ordinary nutrient media without any accessory substances, *e.g.* nutrient agar, are quite adequate. The optimum temperature is about 37° C. for the group as a whole, with an upper limit of 42° C., down to 10° C. or lower. However, *Bact. coli* grows at 44° C., whereas *Bact. aerogenes* grows only poorly or not at all at this temperature: also many strains of *Bact. aerogenes* have an optimum temperature nearer 30° C. than 37° C.

Resistance. Most members of this group are destroyed by exposure to a temperature of 55° C. for 1 hr., or of 60° C. for 15 min. Those of faecal origin have, on the whole, a greater resistance to heat than the other closely related strains, and a small proportion of them are not destroyed by commercial pasteurisation time-temperature combinations.[3, 4] All species may remain alive for weeks or months when present in untreated water stored under atmospheric conditions.

Biochemical activities and differentiation. Coliform organisms are closely related to the pathogenic groups Salmonella and Shigella, which give rise to food-poisoning, typhoid, dysentery, etc., and from which they are clearly differentiated by their ability to ferment lactose with the production of acid and gas.

It has long been recognised that this group was composed of a number of strains which could be divided into two broad sub-groups, *Bact. coli* and *Bact. aerogenes*, on the basis of biochemical tests.[5, 6, 7] Further work has resulted in the definition of a number of intermediate and irregular strains. In addition, there exists a close correlation between these characters and habitat[8] (*see* Table I).

Voges-Proskauer (V.P.) test. Described by Voges and Proskauer in 1898[9] and further elucidated by Harden,[10] this test is of fundamental importance in distinguishing between *Bact. coli* and *Bact. aerogenes.* When grown in dextrose broth, the latter has the property of producing acetylmethyl carbinol by condensation of two molecules of acetaldehyde, itself a product of dextrose fermentation.

$$2\,CH_3.CHO \rightarrow CH_3.CO.CHOH.CH_3.$$

In the presence of alkali and atmospheric oxygen, this compound is oxidised to form diacetyl.

$$CH_3.CO.CHOH.CH_3.\xrightarrow[O]{KOH} CH_3.CO.CO.CH_3$$

Diacetyl reacts with the peptone (creatine) of the broth to give a red colour.

Medium.[11] Glucose phosphate broth.

Peptone	5 g.
Dipotassium hydrogen phosphate (anhydrous)	5 ,,
Distilled water	1000 ml.

Steam until the solids are dissolved: filter hot through Chardin paper, and adjust the reaction at room temperature to *p*H 7·5. Add 5 g. of glucose, mix thoroughly, distribute in 4 ml. quantities into 6 × ⅝ in. test tubes, and autoclave at 10 lb. for 10 min. Test for sterility by incubation at 37° C. for 24 hr.

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[3] Wilson *et al.*
[4] Crossley (1946), *JDR*, **14**, 3, 233–282.
[5] Escherich (1885), *Forschr. d Med.*, **3**, 515, 547.
[6] Durham (1901), *J. Exp. Med.*, **5**, 353.
[7] MacConkey (1905), *JH*, **5**, 333; (1909), *ibid.*, **9**, 86.
[8] Winslow and Walker (1907), *Science N.S.*, **26**, 797.
[9] Voges and Proskauer (1898), *Z. f. Hyg.*, **28**, 20.
[10] Harden (1906), *Proc. Roy. Soc. B.*, **77**, 424.
[11] (1939), *Rep. Publ. Hlth. Med. Subj.*, London, No. 71.

Technique.[11] Inoculate tubes of glucose phosphate broth with a loopful of stock peptone water cultures 4 to 6 hr. old, and incubate for not more than 2 days at 30° C.[12] A knife point of creatine is then added to each tube, followed by 5 ml. of 40 per cent. (w.v.) KOH, and the tubes shaken for 2 to 5 min. If positive, a pink colour develops: if negative, there is no colour change.

Methyl red (M.R.) test. This is an indicator test for detecting the presence of acid products of fermentation.[13] The high negative correlation between this and the V.P. test is possibly due to the fact that, whereas the aerogenes strains form acetyl methyl carbinol from acetaldehyde, those strains which are M.R. +, *i.e.* coli-like, oxidise acetaldehyde to acetic acid: $CH_3 . CHO \xrightarrow{O} CH_3 . COOH$. In the case of *Bact. aerogenes*, fermentation produces a low initial *p*H, which later rises owing to the further breakdown of organic acids, while coli strains maintain a low *p*H level.

Medium.[11] Glucose phosphate broth, as for V.P. test above.

Technique.[11] Tubes are inoculated as for the V.P. test and incubated at 30° C. for 5 days.[12] Five drops of 0·04 per cent. solution of methyl red are then added to each tube. A magenta red colour indicates a positive result and a yellow colour is negative.

Gas ratio. A further indication of the two distinct kinds of fermentation shown by this group is given by an analysis of the gas produced.[14, 15] The gas collected in a fermentation tube as the result of growth of coliform organisms consists almost entirely of a mixture of hydrogen and carbon dioxide, the proportions being measured by absorbing the CO_2 with KOH; *Bact. coli* gives a gas ratio of 1 : 1, while *Bact. aerogenes* produces 2 parts of CO_2 to 1 part of hydrogen. As this property is so closely correlated with other properties, such as the production of acetyl methyl carbinol, it is now mainly of academic interest.

Growth in citrate. In addition to the main cleavage in the group on the basis of the above tests, it was later shown[16, 17] that a group of organisms exists with properties intermediate between the two main types. If citrate is provided in a synthetic medium as the sole source of carbon, *Bact. coli* is unable to utilise it and will not grow, while *Bact. aerogenes*, on the other hand, can use this substance. In addition, a group of organisms with V.P. – and M.R. + reactions (coli-like) can make use of citrate. Some authors consider this sufficient grounds for awarding generic status (*Citrobacter*) to V.P. – M.R. + Citrate + organisms, but it is usual in this country to classify them as "intermediates". The value of this test has been well established.[18, 19, 20]

Medium.[11] Koser's Citrate Medium.

Sodium chloride	5·0	g.
Magnesium sulphate	0·2	,,
Ammonium dihydrogen phosphate . . .	1·0	,,
Dipotassium hydrogen phosphate (anh.) . .	1·0	,,
Distilled water	1000	ml.

This mixture forms a clear colourless solution with a *p*H of 6·8. Add 2 g. of citric acid, and bring back the reaction to 6·8 with NaOH solution. Tube in 5 ml. quantities and autoclave at 15 lb. for 10 min. Test for sterility by incubation at 37° C. for 24 hr.

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[12] Vaughn, Mitchell and Levine (1939), *J. Amer. Wat. Wks. Ass.*, **31**, 993.

[13] Clark and Lubs (1915), *J. Inf. Dis.*, **17**, 160.

[14] Smith (1895), *Amer. J. Med. Sci.*, **110**, 283.

[15] Harden and Walpole (1906) *Proc. Roy. Soc.*, **77**, 399.

[16] Brown (1921), *Lancet*, i, 22.

[17] Koser (1923), *JB*, **8**, 493

[18] Bardsley (1926), *JH*, **25**, 11.

[19] Bardsley (1934), *ibid.*, **34**, 38.

[20] Pawan (1931), *J. Trop. Med. Hyg.*, **34**, 229.

Technique.[11] Tubes of citrate medium are inoculated from stock peptone water culture 4 to 6 hr. old using a straight wire, not a loop, so as to carry over as little as possible of the inoculating medium, then incubated for 48 hr. Opacity is considered evidence of growth. In cases of very slight growth, a 0·008 per cent. concentration of brom-thymol-blue may be added, when the colour changes from the original pale green to a bluish-green or blue. Occasionally no growth occurs for 3 to 4 days.

Indole test. Originally regarded as a means of distinguishing faecal from non-faecal members of the group, the property of indole production is common to some intermediate and aerogenes strains, and the test therefore serves mainly to differentiate faecal from non-faecal coli, about 93 per cent. of strains from human and animal faeces giving a positive reaction.[2]

Medium.[11] Peptone water.

As indole is a product of tryptophane breakdown, the peptone used must contain this amino acid. Batches should be tested with a known indole producing organism.

Peptone	10 g.
Sodium chloride	5 ,,
Distilled water	1000 ml.

Steam until the solids are dissolved. Filter hot through Chardin paper and adjust the reaction at room temperature to *p*H 7·5. Tube in 5 ml. quantities and autoclave at 15 lb. for 20 min. The reaction of the finished medium should be *p*H 7·4 to 7·6.

Technique.[11] The stock peptone water culture, after inoculating from it for other tests, is incubated for 3 days at 37° C. and 1 ml. of ether is then added with vigorous shaking. On standing for about 2 min., the ether layer separates out, and a few drops of Ehrlich's reagent (4 g. paradimethylamidobenzaldehyde, 380 ml. 96 per cent. alcohol, 80 ml. conc. HCl) allowed to run down the inside of the tube. If the test is positive, a pink ring appears at the top of the liquid, due to the combination of the benzaldehyde with the indole present in the layer of ether, to form a rosindole compound.

Gelatin liquefaction. Coliform species may be further differentiated by their proteolytic powers, those liquefying gelatin being given the specific name *Bact. cloacae*. In addition, a few comparatively rare strains which do not fall into any of the main divisions, known as irregulars, have this property.

Medium.[11] Nutrient gelatin.

Yeastrel	3 g.
Peptone	5 ,,
Gelatin (Coignet gold label)	120 ,,
(in hot weather)	150 ,,
Distilled water	1000 ml.

Dissolve in steamer, cool to 30° C., and adjust reaction to *p*H 7·2, using phenol red as indicator: tube in 10 ml. quantities and sterilise at 10 lb. for 15 min.

Technique.[11] A stab culture is made using a straight wire charged with stock peptone water culture, and the tube incubated at 20° to 22° C. for up to 28 days.

44° C. MacConkey Test (Eijkman test). Introduced by Eijkman in 1904, this test is designed to distinguish faecal coli strains from others. It depends on the fact that nearly all faecal coli strains form acid and gas from lactose at 44° C., while very few non-faecal strains are able to do so.[3] The test has been the subject of much controversy, but it has been shown[2, 21] that reliable results can be obtained when the temperature is very accurately controlled at 44° C., *e.g.* of 193 M.R.+, V.P. — citrate — indole + coli strains 180 gave a positive MacConkey reaction at

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[21] Levine, Epstein and Vaughn (1934), *AJPH*, **24**, 505.

44° C., whereas of 303 other strains, 40 of which belonged to the indole-negative coli group, only 10 did so. Best results are obtained with a forced-circulation water bath regulated by a mercury-toluol thermostat.

Medium.[11] MacConkey broth (*see* below).

Technique.[11] A tube of MacConkey broth is heated in a water bath to 44° C. and inoculated lightly from the peptone water culture: it is then immediately returned to the 44° C. water bath, and examined after 18 to 24 hr. The presence of gas in the enclosed Durham tube is taken as a positive reaction. Some strains require 48 hr. incubation, while occasionally 72 hr. is necessary.

The Isolation and Purification of Coliform Organisms from Milk and Milk Products. Preliminary enrichment by inoculation of serial dilutions of the material into MacConkey broth is the standard method in this country. Positive tubes are then streaked on solid media, and the cultures purified by subsequent plating and streaking. Suitable solid media are MacConkey agar, eosin methylene blue agar, and Endo agar.[11] Crossley [11] favours E.M.B. agar, and states that on occasion yeastrel milk agar may prove useful for separation of colonies.

The isolation of pure cultures of coliform organisms is, in practice, a procedure of considerable difficulty, owing to the frequent occurrence of mixed colonies [4] and it seems probable that many of the atypical results of differential tests which have been obtained in the past are due to this factor. Purification of cultures is frequently laborious and may involve many replatings, and it follows that, owing to varying growth rates of different strains, the types finally isolated may bear little relation to the original flora. It is thus impossible to make a complete differentiation of coliform organisms as a routine, although Wilson [3] has suggested a shortened method for estimating coli and aerogenes. About 80 per cent. of red colonies on MacConkey agar are coli-aerogenes bacteria.

Classification of Coliform Organisms.

TABLE Cla I

Type	*Habitat*	*M.R.*	*V.P.*	*Citrate*	*Indole*	44° C.	*Gelatin*
Coli I	Human and animal intestine	+	−				
Coli II	Doubtful	+	−				
Intermediate I	Soil	+	−				
Intermediate II	Soil	+	−				
Aerogenes I	Vegetation	−	+				
Aerogenes II	Vegetation	−	+				
Cloacae	Vegetation	−	+				
Irregular I	Human and animal Intestine	+	−				
Irregular II		+	−				
Irregular III	Not intestinal	+	−				
Irregular IV	Not intestinal	+	−				
Irregular V	Not intestinal	−	+				
Irregular VI	Not intestinal	−	+				
Irregular VII	Not intestinal	−	−				
Irregular VIII	Not intestinal	−	−				

The above table is Wilson's classification :[3] for other schemes *see* Crossley [4] and Malcolm.[22]

[22] Malcolm (1933), *JDR*, **5**, 15.

Incidence of Coliform Types in Milk and Dairy Products.

TABLE Cla II

Product	*Date*	*Author*	*No of cultures studied*	*Percentages found of main coliform groups*		
				Coli	*Aerogenes* + *cloacae*	*Intermediate* + *irregular*
Raw milk	1930	Kline	407	35·0	51·0*	14·0†
	1933	Malcolm	797	54·2	25·0	21·0†
	1933	Yale	91	63·0	26·0*	11·0†
	1935	Wilson	245	30·2	37·5	32·4
	1937	Oeser	164	50·0	34·2*	15·8
	1937	Bartram & Black	310	57·0	22·0*	21·0†
	1940	Griffin & Stuart	1358	16·5	58·6*	24·9
	1946	Crossley	228	55·2	30·3	14·5
Holder-pasteurised milk	1933	Yale	21	57·0	10·0*	33·0†
	1935	Wilson	46	41·3	23·9	34·8
	1937	Bertram & Black	15	6·7	6·7*	86·7†
	1939	Messner & Canessa	301	13·9	18·9	67·1†
	1946	Crossley	185	75·7	16·2	8·1
Ice cream	1933	Yale	16	31·0	56·0*	13·0†
	1938	Nelson *et al.*	86	30·2	62·8*	7·0†
	1946	Crossley	56	35·7	39·3	25·1
Pasteurised cream	1935	Pont	128	76·5	11·0*	12·5†
	1946	Crossley	205	46·3	36·6	17·0
Butter (normal)	1937	Rice	107	58·9	17·8	23·3
Butter (defective)	1932	Hammer & Yale	25	Nil	88·0	12·0†
	1946	Crossley	310	46·4	43·9	9·7
Sweetened condensed milk	1946	Crossley	222	31·1	64·0	4·9
Cheddar cheese	1946	Crossley	277	68·6	15·2	16·2

* Cloacae strains not recorded separately from aerogenes.
† Irregular strains not recorded separately.

Taken from Crossley.[1]

The Enumeration of Coliform Organisms in Milk and Dairy Products. Direct plating is theoretically the soundest method, but in practice gives rise to serious difficulties. So far no medium has been devised which will differentiate with certainty between coliform organisms and others. Either the count is too high owing to the growth of non-coliform organisms, or too low due to their exclusion on over-selective media, nor is it easy to demonstrate gas production on solid media. The alternative is the dilution method, which consists of making serial dilutions of the material under test, inoculating equal quantities of each dilution into a liquid medium, observing changes produced as a result of growth and repeating the results in terms of the smallest amount of the original material to contain coliform organisms or in terms of the probable numbers of organisms per unit volume of the material. This method also has considerable disadvantages, which are discussed below, and can only be regarded as the lesser of two evils when compared with the plating method.

An outline of the standard method formerly applied to designated raw milk in this country is given below.[23]

Apparatus

(1) Test tubes 6 × $\frac{5}{8}$ in., B.S.S. No. 625.

(2) Durham tubes $1\frac{3}{8}$ × $\frac{3}{16}$ in., B.S.S. No. 625 (in practice, 2 in. × $\frac{3}{8}$ in. tubes facilitate examination for gas production as these project above the level of the medium in the test-tube).

(3) Dilution tubes 6 × $\frac{3}{4}$ in., B.S.S. No. 625.

(4) 1 ml. pipettes, straight-sided, calibrated to deliver 1 ml. of water at 20° C. when the contents are blown out with the tip touching the side of the vessel, 3 sec. allowed for drainage and the remaining drop then blown out The amount delivered should be between 0·980 and 1·020 ml.

(5) Cotton wool for plugging test tubes.

Medium. MacConkey broth (single strength).

Commercial sodium taurocholate	5 g.
Lactose	10 ,,
Peptone	20 ,,
Sodium chloride	5 ,,
Tap water	000 ml.

Steam to dissolve the ingredients and filter cold through Chardin paper. Adjust the *p*H to 7·4 using phenol red as indicator. Add about 10 ml. of a suitable indicator (1 per cent. aqueous solution of neutral red, or 0·2 per cent. bromcresol purple). Tube in 5 ml. quantities with a Durham tube in each test tube, plug with cotton wool and sterilise by autoclaving at 10 lb. for 15 min. or steaming for 30 min. on 3 successive days. The finished medium should be clear.

Diluent. Sterile quarter-strength Ringer's solution should be used, tubed in 9 ml. quantities with aseptic precautions, using a special burette or a 9 ml. pipette.

Method. One ml. of the thoroughly mixed sample is inoculated into a tube of diluent, and a fresh pipette used to mix the 1/10 dilution and to transfer 1 ml. of this into a second dilution tube. Another fresh pipette is used to mix this 1/100 dilution and to inoculate 1 ml. into each of 3 tubes of MacConkey broth. These are incubated at 37° C. for 2 days, and if at least 2 out of the 3 tubes are free from acid plus gas, the milk is regarded as satisfactory.

The above technique may be varied for routine purposes and for different products, *i.e.* the quantities inoculated must be designed to cover the expected range of coliform population. Products such as sweetened condensed milk require inocula of 10 or 50 ml. to demonstrate the presence of coliforms, while others may require a number of high dilutions. Where heavy inocula are required, a correspondingly large amount of culture medium must be used, preferably with half the normal water content (double strength MacConkey broth).

In America, standard methods involve the use of brilliant green lactose peptone bile and formate ricinoleate broth for the dilution method, and violet red bile agar and desoxycholate agar for direct plating.[24]

Mackenzie *et al.* (1948, *JGM*, **2,** 197) have devised a rapid method for the detection of faecal *B. coli* Type I.

After preliminary enrichment in MacConkey broth at 37° for 24 hr. (or 42° for 18 hr. and 37° for 6 hr.) inoculation is made into brilliant green bile broth and peptone water at 44°. After a further 24 hr. incubation, gas and indol production (at 44°) can be assumed to indicate a *B. coli* Type I.

An interesting recent paper is that by Burman and Oliver (1952, *SAB*, **15,** 1) who have shown that Folpmer's glutamic acid medium in ordinary plugged tubes gives results very similar to those obtained with MacConkey's for coli-aerogenes bacteria. The advantages of a synthetic, reproducible and cheap medium will be obvious.

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[23] (1937), *Min Hlth. Memo.*, 139/Foods.

[24] *SMDP.*

Errors of the Presumptive Coliform Test. (1) ***Qualitative errors.*** Occasionally non-coliform organisms are encountered which will produce a positive reaction in MacConkey broth. The organisms principally concerned are yeasts and anaerobes: the latter are of special importance with certain products, such as processed cheese and milk powder,[4] but yeasts appear to be of less significance, while false-positives due to any organism are rare with raw milk.[3, 4] The number of false-positives appears to be increased with large inocula and with increasing age of stored products such as hard cheese and condensed milk. For a full discussion of this subject *see* Crossley.[4]

(2) ***Quantitative errors.*** The presumptive coliform test as applied to milk is subject to very considerable sampling errors, and even where an estimation of the total number of coliform organisms is required, a large number of tubes should be inoculated for each dilution, if any degree of accuracy is required. Halvorson and Ziegler[25] concluded that with 40 tubes for each dilution, the probable count would vary between 38 per cent. below and 47 per cent. above the true value, while with 5 tubes for each dilution, the variation would be between 70 per cent. below and 260 per cent. above the true value.

If, in addition, an estimation is required of the proportion of different strains present in a sample, further errors may arise as a result of one type outgrowing the other during incubation, or of the "diluting out" of a strain, so that the distribution of types on plates streaked from positive tubes may bear little relation to the distribution in the original material.

Value and Interpretation of the Coliform Test. The presence of coliform organisms in milk, even of faecal coli, is of doubtful significance from a public health aspect, although they may, when present in sufficient numbers, produce faults and off-flavours. When applied to water, over 90 per cent. of positive tests in this country are due to the presence of faecal coliform organisms,[19] which are very often derived from human excreta, and so must be regarded as indicating the possible presence of pathogenic organisms. In addition, coliform organisms, far from growing in water, tend to die out rather quickly, so that the test probably underestimates the coliform population of a water.

On the other hand, the greater proportion of coliform organisms in milk is made up of the intermediate-aerogenes-cloacae types, which are derived from soil, grain, fodder, etc., while the faecal coli types piesent appear to originate from unsterile utensils as much as from direct contamination of the milk with cow-dung. Milk is also a very good medium for the growth of coliform organisms, and unless kept at less than 40° F. before testing, an entirely misleading picture of the original conditions of production may be obtained from the presumptive test.

Thus the interpretation of the test applied to milk is fundamentally different from its application to water, and its value in dairying varies with the product concerned. In general, the presence of coliform organisms indicates that conditions are such as to allow a general, and undesirable, bacterial contamination to occur, which may adversely affect the quality of the product.

(1) ***Raw undesignated milk.*** In general, a negative coliform result (1 ml.) is rarely met with in ordinary farm or bulked tank supplies, but would indicate eminently satisfactory methods of production and handling, while a positive result would not necessarily indicate the converse.

(2) ***Raw designated milk.*** Milk produced under very clean conditions frequently gives negative results from 1 ml. quantities even when tested some time

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[25] Halvorson and Ziegler (1933a), *JB*, **26**, 101; (1933b), *ibid.*, **26**, 331; (1933c), *ibid.*, **26**, 559.

after production, and the test thus serves to indicate conditions of production to some extent.[3]

(3) ***Pasteurised milk.*** Although a considerable number of strains isolated from pasteurised milk prove to be heat-resistant on further examination, they are probably derived from plant surfaces rather than from the raw milk: the latter normally contains a much lower percentage of heat resistant strains than pasteurised milk.[4] Nevertheless, it is possible that positive presumptive tests may be obtained as a result of coliforms passing through the heating section of a well-run plant in a limited number of cases.

As the pasteurising process consists of several stages, interpretation must refer to the point of sampling. If milk is sampled on leaving the heating section, positive results (10 ml. inocula are usually necessary) indicate underheating or raw milk contamination. Elsewhere and prior to bottling, positive results indicate faulty plant cleaning, while bottling operations are a frequent source of coliform contamination[26] and samples taken in filled bottles may indicate any of the above errors. Samples taken during distribution will also measure to some extent the conditions of storage after bottling, and if these are unsatisfactory, a light initial contamination will be heavily increased: thus the incidence of positive coliform tests on bottled pasteurised milk is much greater in summer than in winter.

(4) ***Manufactured products.*** Nearly all dairy products receive some form of heat-treatment in modern practice, and principles of testing and interpretation may be applied similar to those used for pasteurised milk. In fact, the coliform test is one of the most valuable plant control tests at present known, and can be used to indicate contamination during ice cream, butter, cheese, powder and condensed milk manufacture, although in some cases large inocula are required and presumptive tests require confirmation if errors due to false positives are to be avoided.[1]

Coliform organisms tend to die out fairly quickly during storage of products such as powder and condensed milk and testing must therefore be carried out soon after production.

Faults Caused by Coliform Organisms. A vigorous reaction follows the inoculation of coliform organisms into litmus milk in the laboratory ; the litmus is reduced, and a firm acid clot produced, usually disrupted by the formation of gas. It is thus natural to suppose that the keeping quality of raw milk will be affected by the presence of these organisms, and although Wilson [3] states that the actual correlation between keeping quality and coliform count is comparatively poor, Barkworth[27] concludes that an increase of one stage, *i.e.* from positive in 1/10 positive in 1/100 in the presumptive test, has an effect on the keeping quality equivalent to a sevenfold increase in plate count. There can be no doubt that the coliform group as a whole is a very active proportion of normal raw milk flora in the promotion of souring, and, in addition, is probably responsible for many taints.

Another fault of raw milk commonly ascribed to coliform organisms, particularly aerogenes strains, is ropiness, although M'Kenzie *et al.*[28] considered that cases of this nature were often due to cocci growing in mixed colonies with aerogenes strains.

Coliform organisms also play a considerable part in the deterioration of pasteurised milk and there appears to be a good correlation between coliform content and low temperature dye tests.[29, 30]

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[26] Vernon and Walker (1936), *SAB*, Paper No. 7.

[27] Barkworth (1934), *JDR*, **6**, 26.

[28] M'Kenzie, Morgan and Parker (1943), *SAB*, p. 34.

[29] Rowlands and Provan (1941), *SAB*, p. 36.

[30] Davis and Watson (1946), *SAB*, p. 81.

With manufactured products, the production of gas by coliform organisms is a common cause of spoilage.

Although they are unable to grow in sweetened condensed milk, evaporated milk is sometimes invaded by these organisms when faulty cans are subjected to water-cooling after sterilisation, resulting in blown tins. Flavour defects of butter are frequently caused by organisms of the aerogenes-cloacae group, particularly when the butter is unsalted.[31] Milk used for cheesemaking, if heavily contaminated with coliforms, may give rise to gassy curd, and the production of acid by starter organisms in such milk may be curtailed,[32] while the association of coliforms with blown cheese is generally recognised.[33] Crossley [4] states that two types of blowing occur: one, due to coli types, develops slowly during storage, the other, due to a mixture of types, with aerogenes predominating, develops rapidly, often in the curd itself. *See* Cheese ; Classification ; Condensed milk ; Ropy milk ; Stability.

Refs.: Thierer (1951), *M*, **6**, 128 (ricinoleate broth); Thomas *et al.* (1951), *SAB*, **14**, 45 (classification); Soc. App. Bact. (1949), *SAB*, No. 2, 3; Lorenz (1949), *IDC*, **2**, 714 ("little plate" method); Burman and Oliver (1952), *SAB*, **15**, 1 (synthetic media); Thomas *et al.* (1953), **16**, 30 (farm waters); Fouad and Richards, **16**, 35 (synthetic media); Thomas and McQuillan (1952), **15**, 41; Olson *et al.* (1952), *Tech. Bull. Minn. Agr. Exp. Stn.*, 202 (thermal death times); Kalshoven (1953), *NMDJ*, **7**, 83 (violet red bile agar); Thomas *et al.* (1951), *SAB*, **14**, 45; Murray (1953), *SAB*, **16**, 24 (30° and 37° C.); Thomas *et al.* (1953), *SAB*, **16**, 30 (farm waters).

COLIFORM MASTITIS. Mastitis can rarely be caused by *Bact. coli.* If persistent bad coli results are obtained for a producer's milk in the absence of any assignable cause, then coliform mastitis should be suspected. *See* Coliforms ; Mastitis.

COLLAPSE OF TANKERS. A collapse of a tanker may result from the cooling and condensing of water vapour after steam sterilising if the tanker is left sealed and without the appropriate valve operating properly. Pumping may also lead to the same effect.

COLLECTION OF MILK. Milk is collected almost universally by lorry from the farm, the Milk Marketing Board now assuming responsibility for this. Usually evening and morning milk is collected together, arriving at the creamery from about 9 a.m. onwards. There is now an intensive effort to get all milk to the depot not later than 2 p.m. Unfortunately, the periods of flush production and very hot weather sometimes coincide so that milk may still be tipped up to 5 p.m. or even later. It is obvious that the bacteriological quality of milk must suffer under such conditions. It is a fallacy to assume, however, that the quality of milk falls and the percentage rejected rises steadily during the day. Some figures show this trend, but others do not. A factor to be considered is the fact that farmers know when their milk arrives at the creamery and this influences the degree of care in production.

In hot weather a twice-daily collection is often arranged, either p.m. milk in the evening, or early in the morning. Another method is the collection of a.m. and p.m. milk together in the evening. *See* Costings ; Management of creameries ; Milk marketing ; Transport.

COLLIN'S RULE. This gives an approximate guide for the effect of length of milking period on the fat content of the milk, the percentage altering by 0·2 per cent. for each hour change in milking interval. The rule works in both directions. *See* Composition, factors affecting.

COLLOIDS. When matter exists in a state of division intermediate to true solution (*e.g.* salt in water) and suspension (*e.g.* chalk in water), it is said to be in colloidal solution or colloidal suspension. In milk the albumin and globulin are in colloidal solution and the casein-calcium phosphate complex in colloidal suspension. The relative sizes of particles in milk are as follow:

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[31] Hammer and Yale (1932), *JDS*, **15**, 199.

[32] Whitehead (1930), *JDR*, **1**, 76.

[33] Yale and Marquardt (1943), *New York St. Agric. Exp. Sta. Tech. Bull.*, No. 270.

Size (mm.)	
10^{-2} to 10^{-3} . . .	Fat globules
10^{-4} to 10^{-5} . . .	Casein-calcium phosphate
10^{-5} to 10^{-6} . . .	Albumin and globulin
10^{-6} to 10^{-7} . . .	Lactose, salts, and other substances in true solution

Bacteria are about 10^{-3} and viruses and bacteriophages about 10^{-4} to 10^{-5} mm.

Colloidal solutions and suspensions owe their stability partly to the size and partly to the electrical charge and affinity for water molecules of their particles

Substances such as salts destabilise colloidal systems by neutralising the charge, and factors such as heat may act by dehydrating the particles; alcohol also acts in this way.

Refs.: Clayton; Rogers; Ward (1948), *Colloids: Their Properties and Applications*, London; Hauser (1939), *Colloidal Phenomena*, London; Marshall (1935), *Colloids in Agriculture*, London; Ford and Ramsdell (1949), *IDC*, **2**, 17.

COLONY. In the agar plate method for enumerating bacteria in milk, etc., the milk or other material is mixed in a nutrient agar jelly and incubated. Each bacterium then multiplies until millions have been formed from the original cell and a bacterial colony becomes visible. The appearance of the colony depends on the type of bacterium, the composition and other properties of the medium, and whether the colony is formed on the surface or in the depth. *See* Classification; Plate count.

Bacterial colonies are sometimes seen in dairy practice, *e.g.* "yellow spot" on bottles consists of colonies of the heat resistant *Sarcina lutea*.

Refs.: Chalmers; Cunningham.

COLOSTRUM. The first milk from the mother after birth of the young mammal. The composition of bovine colostrum changes rapidly during the first few days (Table Co I).

TABLE Co I

Days after calving	*Specific gravity*	*Chloride* (%)	*Acidity* (% "*lactic acid*")	*Freezing-point* (° C.)	*Casein* (%)	*Albumin and globulin* (%)	*Lactose* (%)	*Fat*	*Clot on boiling*
0	1·067	0·153	0·41	−0·605	5·08	11·34	2·19	5·1	+
1	1·034	0·156	0·24	−0·575	2·76	1·48	3·98	3·4	+
2	1·032	0·149	0·22	−0·580	2·63	0·99	3·97	2·8	+
3	1·033	0·137	0·23	−0·575	2·70	0·97	4·37	3·1	0
4	1·034	0·135	0·21	−0·555	2·68	0·82	4·72	2·8	0
5	1·033	0·131	0·19	−0·575	2·68	0·87	4·76	3·75	0
7	1·032	0·113	0·20	0·570	2·42	0·69	4·96	3·45	0

After 15 days the milk is practically normal.

See Abnormal milk; Milk secretion; Nutritive value; Pigs.

Refs.: Davies; Richmond; Rogers; Moody *et al.* (1951), *JDS*, **34**, 106.

COLOUR. The colour of all foods is an important aspect of their marketability; no food, however good in other respects, has any market or is attractive to the consumer unless the colour is that traditionally associated with the product. Colour has three aspects that must be satisfactory: (*a*) tint; (*b*) intensity; (*c*) uniformity. Of these, variations in intensity can be most tolerated since these inevitably occur in practice; any marked deviation from the typical tint, however, or any mottling in a product that is not normally mottled, is a serious defect and greatly detracts from the commercial value of the product.

There is no object in highly accurate assessment of colour in foods and the Tintometer is quite adequate for all ordinary purposes.

The colour of milk is largely controlled by the feed but some breeds, especially the Channel Islands, are always more coloured due to the fact that the fat contains more carotene and less vitamin A (relatively) than the other breeds (*see* Vitamin A).

The colour of butter, and also cheese, is determined by the carotene content of the fat and by certain other factors such as the physical texture of the product, evaporation of moisture, and microbiological activity. *See* Annatto.

Ref.: Chamberlin (1951), *CIE. international colour system explained*, Tintometer Ltd.

COLOUR FAULTS. (i) *Milk.* A blue colour is produced by *Ps. syncyanea* in the presence of acid. A yellow coloration is most commonly caused by *Flavobacterium synxanthum.* Red colours in milk may be caused by *Serratia marcescens* (*B. prodigiosum*) or by pink yeasts of which the most common is *Torula glutinis.* Milk held at low temperatures may develop a greenish sheen or fluorescence due to the growth of *Ps. fluorescens.* (ii) *Cheese, see* p. 168. (iii) *Butter.* Colour faults are most commonly due to moulds, but a few are of bacterial origin (p. 968). (iv) *Condensed milk.* Yeasts are sometimes responsible (p. 287). (v) *Evaporated milk.* Spore forming organisms may produce discoloration (p. 289). *See also* Classification; Stability.

Refs.: Bergey; Chalmers; Hammer.

COLOURING MATTERS. It is illegal to add any colouring matter to milk, but annatto may (normally) be added to cheese, butter, and other dairy products.

Coal tar dyes, particularly azo colours, were formerly used.

For the detection of colouring matters *see* Richmond.

COMMENSAL. An organism living in useful but not obligatory association with another. Symbiosis (p. 1005) implies a *necessary* association.

COMMERCIAL BUTTER-MILK.

Refs.: Whittier and Webb.

COMMERCIAL STERILITY. A term (not approved by bacteriologists) to denote the reduction of micro-organisms in dairy plant to an agreed number, *e.g.* 1 per ml. or 5000 per sq. ft. *See* Bottle washing; Churn washing; Cleaning.

COMPARISON OF CHEMICAL AND BACTERIOLOGICAL TESTS FOR MILK. These differ for two fundamental reasons: (i) The chemical qualities of milk remain constant whereas the number of bacteria is always altering. (ii) Whereas the yardstick or quality being measured is clearly understood and definable for chemical tests, the term " bacteriological quality " is capable of a number of meanings. Thus it may refer to (*a*) the total number of bacterial cells, living and dead; (*b*) the number of bacterial cells *or clusters* capable of growing and forming colonies in a nutrient medium; (*c*) the biochemical activity of the bacteria present without reference to numbers of individual types; (*d*) the rate at which the bacteria can grow and form lactic acid and rennet, *i.e.* the keeping quality of the milk. It is for this reason that there has been so much controversy over the question of what is the best test for the bacteriological grading of milk.

In addition, there is a third difference—the error or variability of bacteriological tests is much greater than that of the chemical tests. *See* Bacteriological grading; Quality payment.

Ref.: Wilson *et al.*

COMPLAINTS. In dairying normally referring to complaints by customers on account of (i) dirty bottles; (ii) poor keeping quality; (iii) unsatisfactory deliveries; (iv) poor cream line. *See* Legal aspects; Public relations.

COMPOSITE SAMPLE. When a number of churns (cans) have to be sampled, the size of sample should be varied according to the volume in each churn. These aliquots should then be mixed in a suitable container and a sample of suitable size taken. *See* Sampling.

COMPOSITION, AVERAGE, OF MILK AND FLUID MILK PRODUCTS.

TABLE Cm I

Product	*Whole milk*	*Skim milk*	*Cream (25 % fat)*	*Cream (50 % fat)*	*Butter-milk*	*Whey*
	%	%	%	%	%	%
Fat . . .	3·75	0·05	25·00	50·00	0·10	0·30
Solids-not-fat .	8·90	9·10	6·80	4·55	9·00	6·55
Total solids . .	12·65	9·15	31·80	54·55	9·10	6·85
Casein . .	2·60	2·65	2·00	1·33	2·65	nil.
Albumin . .	0·50	0·52	0·39	0·25	0·52	0·52
Globulin . .	0·20	0·21	0·15	0·11	0·21	0·20
Lactose . .	4·85	4·95	3·71	2·47	4·95	5·00
Ash . . .	0·72	0·74	0·56	0·37	0·74	0·54
Water . . .	87·35	90·90	68·20	45·45	90·90	93·15

There are seasonal variations in the fat and solids-not-fat of bulked milks, the former being at a minimum from April to June, and at a maximum from November to January, and the latter at a minimum from July to August, and at a maximum from November to January. *See also* Average composition ; Pigs.

COMPOSITION OF MILK, FACTORS AFFECTING. The composition of milk is probably the most important scientific aspect of the whole dairy industry and a knowledge of the factors affecting it should be possessed by all persons holding responsible positions in the industry.

As might be expected, the more the bulking the more constant the composition of milk tends to be. Fluctuations in the composition of milk from a single cow may be quite startling, while that of milk sold by a large distributor will be remarkably uniform.

The significance of the more important factors known to affect composition (fat and solids-not-fat) is discussed below.

(1) **Individuality of the Cow.** By sampling enough cows it would be possible to obtain milk of almost any composition over a certain range. This is well illustrated by the following figures by Overman, Sanman and Wright (1929 *Bull.* 325, Univ. Illinois, Agr. Expt. Sta.).

Range of Results

Breed	*Fat*	*Solids-not-fat*	*Total solids*
Jersey	3·28 to 9·37	7·68 to 11·07	10·96 to 17·68
Guernsey . . .	3·65 to 7·66	8·19 to 11·10	12·07 to 17·88
Ayrshire	2·92 to 5·66	7·20 to 10·34	10·56 to 15·76
Friesian (Holstein) .	2·60 to 6·00	7·82 to 11·90	10·72 to 17·62

(2) **Intervals Between Milkings.** This affects very considerably the fat (*see* Collin's rule) but has little effect on the solids-not-fat.

(3) **Frequency of Milking.** Very heavy yielders may be milked three times a day. Gilchrist found the following figures:

	5 *a.m.*	1 *p.m.*	6 *p.m.*
Fat, %	3·36	4·26	4·16
Solids-not-fat, % .	8·94	9·00	9·21

(4) **Variation During Milking.** The fat content invariably increases during milking. The differences are most marked with morning milk and high-yielding cows. Gravity cannot explain this as an animal milked on its back gives the same trend of results (Bartlett (1934), *JDR*, **5**, 113).

(5) **Milking Personnel.** Both fat content and yield may be adversely affected if the cow does not take kindly to the milker.

(6) **Age of Cow.** Fat content decreases with age. In one test with Ayrshire cows, the fat fell from 3·85 to 3·42 per cent. (13 year old group) (Crowther (1905), *JAS*, **1**, 156). The solids-not-fat usually falls slightly but steadily with increasing age (Tocher).

(7) **Breed.** Figures vary according to their source but the following have been obtained from groups of cows under specified conditions.

	Fat (Tocher)	*Fat* (Drakeley, B D F.A.)	*Solids-not-fat* (Drakeley, B D F.A.)
Jersey	5·43	5·18	9·30
Guernsey . .	5·16	4·88	9·29
Kerry . . .	4·67	4·30	9·09
Dexter . .	—	4·15	9·11
South Devon . .	—	4·02	9·25
Welsh	4·40	—	—
Red Poll .	—	3·81	9·09
Ayrshire . . .	4·09	3·97	9·00
Shorthorn . .	1	3·78	9·04
Lincoln Red . . .		3·76	9·00
Friesian .	3·63	3·67	8·78

See also Breeding.

(8) **Stage of Lactation.** Both fat and solids-not-fat fall until about the third month of lactation, after when both rise steadily. Typical figures are:

Month of lactation	*Fat*		*Solids-not-fat*	
1	3·78	4·00	8·95	8·74
2	3·40	3·85	8·72	8·41
3	3·35	3·79	8·74	8·50
4	3·38	3·77	8·84	8·47
5	3·56	3·82	8·81	8·53
6	3·86	3·79	9·03	8·71
7	4·05	3·83	9·00	8·78
8	4·05	3·85	9·17	8·85
9	4·17	3·97	9·10	8·81
10	4·27	4·11	9·29	9·05
11	4·70	4·22	9·49	9·24

1st column: Crowther (l.c.)
2nd column: Eckles and Shaw (1913), U S. Dept. Agr., *Bull.* 155.

(9) **Sexual Excitement.** Considerable individual variation is noticeable but there is a tendency for the fat to be low immediately before the period, and for yield and fat to be low on commencement and then high at the next milking.

(10) **Day-to-day Variation.** This is of great interest to the producer in view of the presumptive standards (p. 602) and the appeal-to-the-cow test (p. 56). On the theory of probability, it is unlikely that all the cows in a herd will vary in the same direction on the same day (excluding weather, etc.). However, it has been known for the milk of a herd of twenty-four cows to vary by as much as 0·6 per cent. fat and 0·87 per cent. solids-not-fat on two successive milkings (*Min. Agric. Bull.* 16).

(11) **Season.** It is difficult to assess this factor as temperature, stage of lactation, feed, etc., are inevitably accompanying factors. Pre-war data show quite clearly that the fat is lowest in June and highest in November; solids-not-fat experience a first minimum in April and a second in July-August. The acute feeding-stuffs position in recent years has resulted in a marked fall in solids-not-fat from February to April.

(12) **Temperature or Climate.** Markedly high or low temperatures tend to lower the yield, but do not appreciably affect the composition.

(13) **Health of the Cow.** Ill-health, in a general sense, tends to lower the yield but does not affect composition except sometimes to increase the fat content. Specific udder disease (mastitis) lowers the solids-not-fat and also the yield; the effect on fat may be nil or variable. *See* Abnormal milk; Mastitis.

(14) **Feed.** There is a cleavage of opinion on this point, practical men claiming that poor feeding lowers both fat and solids-not-fat while scientific investigations do not always support this claim. It is important to distinguish between short time experiments, *e.g.* of 3 months, and the cumulative effect of prolonged underfeeding. Feeding potatoes in large amount may cause a sharp fall in the fat.

Broadly speaking, a change in the quantity or quality of the feed will affect yield but not composition. There are a few recognised exceptions. For example, feeding excessive amounts of cod liver oil will lower the fat, and an excessive proportion of low starch and protein ration, *e.g.* white turnips may lower the solids-not-fat. Turning cows out to grass may result in a lowering of the fat and a raising of the solids not-fat. The latter effect has been very noticeable following the underfeeding in winter during the war.

The evidence on the effect of *different types* of feed is contradictory (*see* Richmond, p. 46). Recent experiments indicate that low calorie and low protein diets may result in low SNF and low fibre diets in low fat values. Fat appears to be synthesised from acetate which may result from the fermentative breakdown of cellulose (*NIRD*, 1950, 1951). It has also been claimed that feeding trace metals, *e.g.* copper, can result in an increase of fat in the milk (Dunlop, 1953, V, **171**, 356, 439). *See* Breeding; Fat; Feeding; Management of dairy cattle; Pigs; Solids-not-fat.

Refs : Min. Agric. (1932), *Variations in the Composition of Milk*, Bull. No. 16, H.M.S.O.; Davies; Richmond; Balch *et al.* (1952), *JDR*, **19**, 39 (fibre on fat content); Bailey (1952), *JDR*, **19**, 89, 102, 109, 115, 169 (variations in SNF). Featherstone *et al* (1951), *JDR*, **18**, 155 (SNF); Neseni and Körpich (1947), *M*, **2**, 389, 405 (protein and fat); Breirem (1949), *IDC*, **1**, 28; Bartlett *et al.* (1949), *IDC*, **1**, 102 (iodinated protein effect); Larsson *et al.* (1949), *IDC*, **1**, 377; Hansson (1949), *IDC*, **1**, 386 (heredity); Vuyst *et al.* (1949), *IDC*, **1**, 597 (fat and albumin); Provan (1949), *IDC*, **2**, 217; Rowland (1944) *JDR*, **13**, 261 (low SNF in winter).

COMPOSITION OF MILK, TRENDS IN. It is frequently stated that the solids-not-fat content of milk in England and Wales has fallen during the past few years. For a general discussion of this problem *see* Davis (1952), *A*, **77**, 499.

CONCENTRATED MILK. A concentrated milk of about 36 per cent. total solids has recently been developed in America. It is usually pasteurised and stored at about 0° C.

Refs.: Burgwald *et al.* (1952), *MD*, **42**, (2) 50; Olson*et al.* (1953), *JDS*, **36**, 817.

CONDENSATION. The opposite of boiling. Commonly condensation occurs when a gas, *e.g.* air, becomes saturated with a liquid vapour, *e.g.* water vapour, due to cooling. *See* Humidity; Refrigeration; Vapour pressure.

CONDENSED AND EVAPORATED MILK. Sweetened and unsweetened condensed milks are produced by the evaporation *in vacuo* of milk, either whole or skimmed and with or without the addition of sucrose. The ratio of concentration of milk solids is about 1 : 2·5 for fullcream products and 1 : 3 for sweetened condensed skim milk while the added sucrose accounts for from 40 to 45 per cent. of the weight of sweetened condensed milk. The term "condensed milk" is often used when referring to sweetened milks while the unsweetened fullcream product is commonly called "evaporated milk".

Sweetened condensed milk is preserved by its high sucrose content, but unsweetened condensed milk must be sterilised after canning.

When sold to the public, condensed milk is subject to certain legal standards with regard to composition and labelling, as set out in the Public Health (Condensed Milk) Regulations 1923 and 1927. It is required that condensed milk shall contain not less than:

	Milk fat (%)	*Milk solids (including fat)* (%)
Fullcream unsweetened	9·0	31·0
Fullcream sweetened	9 0	31·0
Skim unsweetened	—	20·0
Skim sweetened	—	26·0

The cans must be labelled in the prescribed manner and the equivalent contents declared. The equivalent is the volume of fullcream or skimmed milk, of standard composition, expressed as pints and half, quarter, or eighth pints, to which the contents of the can may be diluted. This standard fullcream milk is defined as containing 3·6 per cent. of milk fat and 12·4 per cent. total solids and has a specific gravity of 1·0320 at 60° F., while the standard skimmed milk contains 9 per cent. of solids-not-fat and has a specific gravity of 1·0355 at 60° F., the milk fat content being negligible.

The following formulae [1] are useful for calculating the equivalent pints of the contents of a can of condensed milk after an analysis has been made:

Fullcream sweetened and unsweetened milk

Equivalent pints on total milk solids $$\frac{\text{T.M.S. \%} \times \text{net weight in grams}}{7255}.$$

Equivalent pints on fat $$\frac{\text{Fat \%} \times \text{net weight in grams}}{2106}.$$

Sweetened condensed skimmed milk

Equivalent pints $$\frac{\text{Solids-not-fat \%} \times \text{net weight in grams}}{5284}.$$

With fullcream products, both equivalents are calculated and the lower figure taken as the true equivalent.

Evaporation *in vacuo* is very rapid and modern plants work at a temperature of 120° F. which corresponds to a vacuum of about 26·5 in. of mercury. The low temperature preserves the colour and flavour of the milk and has a minimal effect on protein stability, factors which largely determine the quality and "shelf-life" of the product. Evaporation in a single effect vacuum pan expends slightly more energy than evaporation at atmospheric pressure, but the use of thermo-compression and double or triple effect pans gives a saving of from 10 per cent. to more than 50 per cent. of the steam consumption of a single effect unit. (Fig. Co 1.)

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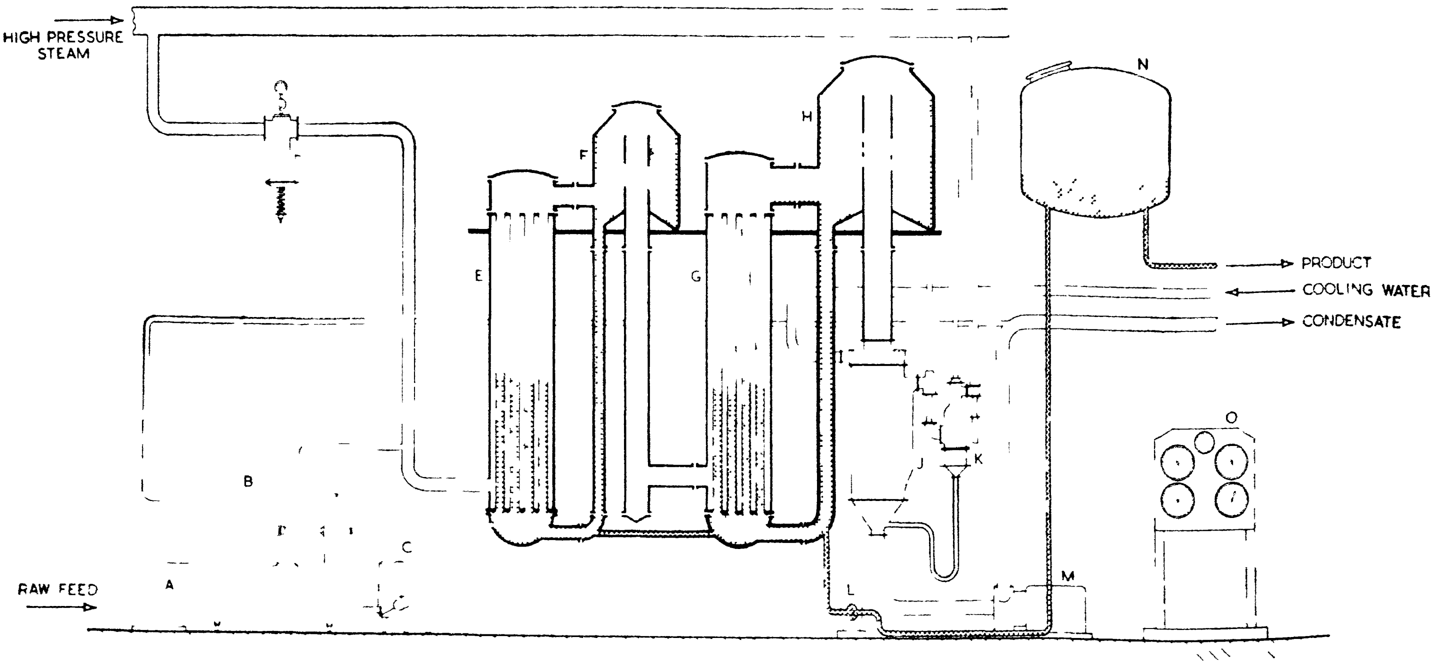
[1] Cox, (1950) *The Chemical Analysis of Foods*, J. and A. Churchill, London.



[By courtesy of A P V. Ltd.

FIG Co 1 —*Double Effect Evaporator*

The evaporator or pan is a cylindrical vessel 4 to 6 ft. in diameter, and 12 to 15 ft. tall, provided with steam heating surfaces, and, at the top, an entrainment interceptor and vapour off-take pipe leading to a condenser (Fig. Co 2). Parts which come into contact with the milk should be of stainless steel and the design should be such that all parts are easily accessible for cleaning. The heating surfaces take the form of either coils or a calandria. When coils are used they are arranged one above the other in the lowest part of the pan and may be 4 to 6 in number. The coils, which are fixed to leave a gap of 6 to 9 in. between the coil and the pan wall to allow free circulation of the milk, are short in length being 1 to 1½ turns and each has its steam inlet valve and condensate trap. Well-designed traps of correct capacity are essential for good performance of the evaporator. The layers of coils make it possible to control the rate of working of the pan by increasing or decreasing the area of the heating surface and also to handle larger or smaller quantities of milk. A calandria can be described as a tubular heater built into and working as part of the evaporator. It consists of a large number of stainless steel tubes expanded into end plates and surrounded by a steam chest. The milk is passed through the tubes by forced or natural circulation. In spite of the large number of tubes in the calandria, pans of this type are generally more satisfactory bacteriologically and the high speed of circulation of the milk over the heating surfaces minimises the formation of deposits, thus making it possible to combine long runs with easy cleaning.

Calandria pans lend themselves to designs which give substantial economies in steam consumption by the use of double and triple effects and thermo-compression. In a double effect evaporator, two pans are joined together, the first one working at a lower vacuum and consequently a higher temperature than the second (Fig. Co 3). The vapour from the first effect is used as the heating medium in the second effect, and the latent heat of the steam used for heating in the first effect is made to do a greater amount of work. The milk is partly condensed in the first effect and passes to the second effect where the process is completed. The design can be further extended to involve three effects. In practice, a difference of about 50° F. (Eg. 170° and 120° F.) is needed between the working temperatures of the two effects in order to ensure efficient heat transfer in the second effect. This may preclude the use of multiple effect evaporation in the case of heat sensitive products, since the temperature required in the first effect may be too high. Condensed milk is commonly produced by single effect evaporation. Such multiple-effect pans are mainly used in the manufacture of unsweetened condensed milk where milk evaporated to the desired concentration is continuously produced without any interruption for emptying the evaporator as in batch processes. Where thermo-compression is used, a part of the vapour produced from the milk is raised in temperature and pressure by means of high pressure steam, and this forms the steam supply for the heating surfaces of the evaporator. Even in the best designed pans the use of the vapour this way may cause slight contamination of the condensate return from the evaporator coils or calandria with milk, making it desirable to run the condensate to waste instead of to the boiler hotwell. In spite of this, however, a considerable increase in thermal efficiency is obtained. In countries where steam-raising fuel is scarce and expensive, and hydro-electric power is plentiful and cheap, mechanical recompression of the vapour from the evaporator is used with great success.

The rate of evaporation depends on the area of the heating surfaces, the temperature difference between the steam and the milk and the speed of circulation of the milk over the heating surfaces. Given adequate means of dealing with the quantity of vapour produced, the temperature difference between steam and milk is best produced by working at as high a vacuum as possible, greater evaporation being obtained in this way than by increasing the steam pressure. The speed of circulation of the milk over the heating surfaces is a matter of good design of the evaporator. The thermal conductivity of the metal used is now known to be relatively unimportant; copper pans were formerly used but have been replaced by stainless steel pans, which are preferable for contact with milk. A large diameter vapour offtake pipe is essential. Small offtake pipes result in high vapour velocities reaching hundreds of ft. per sec. with very appreciable frictional effects and entrainment losses are increased. Entrainment, that is the carry-over of spray from the boiling milk, not only means inefficient production, but also may lead to difficulties with the disposal of the condenser effluent. The interceptor chamber on the top of the pan and from which the vapour pipe is taken, is designed to lower the speed of the vapour and cause it to deposit the droplets of milk spray. The collected entrainment may be allowed to return to the pan and therefore the interceptor and vapour pipe must be readily accessible for daily cleaning and sterilisation. It is, however, preferable on strictly bacteriological grounds to pass the material through the heat treatment process again before it re-enters the vacuum pan. Entrainment can be largely (but not entirely) prevented by working the pan at the proper level, producing a generous vapour space in the pan above the working level and reducing vapour velocity by means of a large diameter offtake pipe which, for a pan of 6 ft. diameter, should have a diameter of at least 20 in.

Not only must the vacuum be produced in the pan, but it must also be maintained throughout the process. Incondensable gases, mainly air introduced with the milk and the cooling water must be continuously removed together with the vapour from the boiling milk. For this purpose the offtake pipe passes into a condenser where the vapour meets with a spray of cold water. In the parallel flow condenser, the vapour enters the top of the condenser and the cooling water spray travels in the same direction. At the condenser exit is a wet vacuum pump which handles both the mixed cooling water and condensed vapour and the incondensable gases. A more efficient type of condenser is made on the countercurrent principle. Here, the vapour enters the lower part of the condenser at the side and travels upwards, the vacuum being produced by either a dry pump or steam ejector from the top of the condenser. The vapour meets a spray of cooling water which enters near the top of the condenser, and the mixed cooling water and condensed vapour leave at the bottom of the condenser. The dry pump or ejector handles the incondensable gases and the condenser effluent is removed either by means of a centrifugal pump or a barometric tail-pipe. For efficient working, the cooling water control valve and a thermometer indicating the temperature of the condenser effluent should be accessible from the pan operating platform. An effluent temperature of 5° to 15° F. lower than the working temperature of the evaporator, depending on the type of plant, is adequate. A lower effluent temperature indicates wasteful use of cooling water and no advantage is gained from it. From 2 to 3 gal. of cooling water are required to condense 1 lb. of vapour, the quantity depending on the temperature of the water supply.

The method of working the vacuum pan is the same whether sweetened condensed or unsweetened condensed milk is made. The clean pan is steamed out, the condenser water turned on and the vacuum produced by either pump or ejector. The milk to be condensed is preheated to a temperature between 170° and 240° F. and is drawn into the pan from a hotwell or holding tank. The preheating process destroys yeasts and moulds and very greatly reduces the numbers of bacteria; it also inactivates enzymes, of which lipase is the most important. The milk as drawn into the pan should contain only resistant bacterial spores. It also has an important effect on the physical properties of the finished product and the milk, being drawn into the pan at a temperature well above its boiling-point at the reduced pressure, does not hinder the brisk boiling in the pan nor the rapid circulation over the heating surfaces which is essential to prevent "burning on". The preheated milk should be held in a closed vessel, so that the formation of a skin on the surface of the milk is prevented. This skin will cause the appearance of small jelly-like lumps of insoluble casein in sweetened condensed milks. When starting the pan, the milk intake valve is widely opened and a rapid stream of hot milk is drawn in. Ebullition immediately takes place and the milk quickly settles down to a rapid boiling. Steam is gradually turned on as the heating surfaces are covered by the milk, and when the depth of milk has reached the working level, the intake valve is adjusted to maintain this level. When the pan has settled down to steady working, the operator watches the vacuum gauge and milk level in the pan and the thermometers showing the pan and condenser effluent temperatures. Loss of vacuum during working is usually due to either vacuum pump failure or loss of cooling water to the condenser, or air drawn in through the milk intake pipe due to emptying of the hotwell. When the whole of the milk (with the sugar in the case of sweetened condensed milk) has been drawn into the pan, the intake valve is closed and the evaporation continued until the desired concentration is reached. This may be from 10 to 15 min. after the last milk has been drawn into the pan, and care must be taken to turn off the steam from any heating surfaces exposed by the fall in milk level during the last stages of concentration. The final operation is " striking " the batch, and experienced operators can tell by the appearance of the boiling milk when striking point is near. The pan is fitted with a device which allows samples to be withdrawn for testing. The concentration of the milk in the pan continues while the sample is being tested, so that testing must be accurate and rapid and allowance must be made for the fact that the result of a test represents the state of the milk in the pan at the instant when the sample was taken. Physical properties such as specific gravity or viscosity which are related to the degree of concentration of the milk are used to determine the striking point. By adjusting the steam supply to the pan and the cooling water to the condenser, the pan temperature must be maintained at a predetermined figure while striking takes place. Specific gravity is generally used for sweetened condensed milk and invariably for unsweetened condensed milk where the increase in viscosity though appreciable is insufficient for use as an index of concentration under factory conditions. For specific gravity measurements, the Beaumé scale is very convenient and hydrometers having a range of 7° to 8° Beaumé graduated in 1/10° Beaumé are generally used.

Unfortunately neither method is completely satisfactory. A hydrometer reading is partly influenced by viscosity as well as by specific gravity, and it is possible to obtain appreciable variations of viscosity for a given solids content. For the same reasons, viscosity measurements may be unreliable, and require at least seasonal adjustment. Some operators prefer to work to a fixed sugar concentration and employ a specially calibrated refractometer for testing purposes. This method is simple and rapid, though possibly of doubtful accuracy for this particular purpose.

The following formula for calculating the specific gravity of condensed milk of known composition and which gives figures closely approximating to reality is given by Hunziker.[2]

Specific gravity at 60° F.

$$\frac{100}{\dfrac{\%\ \text{milk fat}}{\text{sp. gr. milk fat}} + \dfrac{\%\ \text{milk solids-not-fat}}{\text{sp. gr. M.S.N.F.}} + \dfrac{\%\ \text{sucrose}}{\text{sp. gr. sucrose}} + \%\ \text{water}}$$

The following values are given :

Specific gravity of milk fat at 60° F.	0·93
Specific gravity of milk solids-not-fat at 60° F.	1·616
Specific gravity of milk sucrose at 60° F.	1·589

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[2] Hunziker (1949), *Condensed Milk and Milk Powder*, Pub by Author, La Grange, Illinois.

The milk solids-not-fat figure is that given by Richmond.[3] With unsweetened condensed milk, the sucrose figure is zero and the variations in the milk solids-not-fat figure due to seasonal and other changes make the formula less reliable.

Specific gravity is converted to Beaumé degrees by the formula:

$$\text{Degrees Beaumé at } 60^\circ\text{ F.} = 145 - \frac{145}{\text{specific gravity at } 60^\circ\text{F.}}$$

Temperature correction factors given by various workers are 0·03° Beaumé for sweetened milk and 0·025° Beaumé for unsweetened condensed milk per degree Fahrenheit. The values are calculated from the figures given below.

As soon as the final test has been made, the pan is shut down by closing the steam supply and condenser cooling water valves and admitting air through the vacuum-break valve on the pan.

In the manufacture of fullcream condensed milks the milk to be used is first standardised so that the fat and solids-not-fat are in the ratio of 9 : 22 or 1 : 2·44. This standardisation ensures that both components reach the required concentration without either of them being over-concentrated thus giving a product of constant physical properties and making the striking of the batch a matter of certainty.

Product	*Composition*	*Specific gravity*		*Degrees Beaumé*	
		60° F.	120° F.	60° F.	120° F.
Fullcream condensed Unsweetened	9% Milk fat 22% Milk solids-not-fat	1·083	1·072	11·2	9·7
Fullcream condensed Sweetened	9% Milk fat 22% Milk solids-not-fat 42% Sucrose	1·303	1·282	33·7	31·9
Skim condensed Sweetened	26% Milk solids-not-fat 44% Sucrose	1·355	1·333	38·0	36·2

To standardise milk which contains milk fat in excess of the desired ratio by the addition of skim milk, the pounds of skim milk to be added to 100 lb. of the unstandardised milk is given by: $\text{Pounds of skim milk} = \frac{100(Bx - Ay)}{Az}$.

When the milk fat in the unstandardised milk is deficient, cream must be added, the amount to be added to 100 lb. of unstandardised milk being given by:

$$\text{Pounds of cream} = \frac{100\,(Ay - Bx)}{BW}.$$

As the solids-not-fat in the cream may be appreciable, it is more accurate to use the formula: $\text{Pounds of cream} = \dfrac{100\,(Ay - Bx)}{BW - \dfrac{9A\,(100 - W)}{100}}$,

which regards the cream as composed of milk fat and skim milk containing 9 per cent. of solids-not-fat.

In the above formulae: A = per cent. fat desired in the finished product; B = per cent. solids-not-fat desired in the finished product; x = per cent. fat in unstandardised milk; y = per cent. solids-not-fat in unstandardised milk; z = per cent. solids-not-fat in skim milk; W = per cent. fat in cream.

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[3] Richmond.

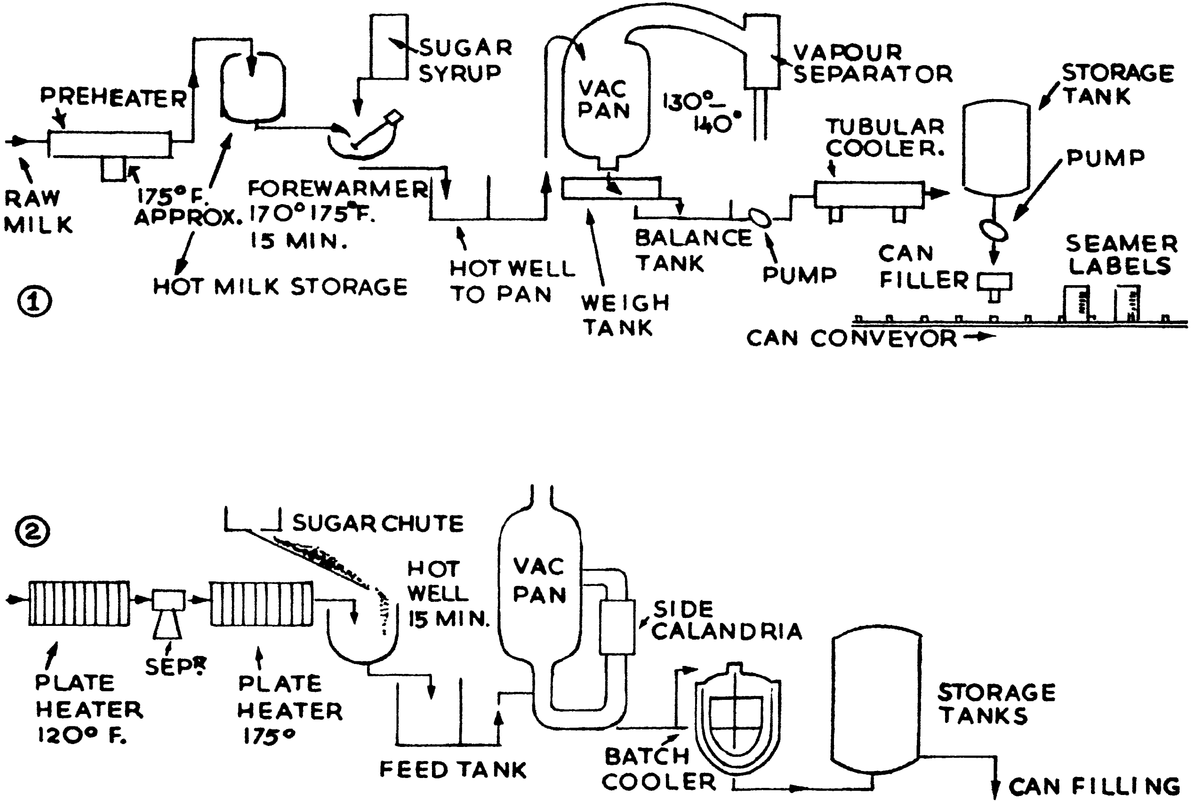

Fig. Co 4.—Flow diagrams for the manufacture of sweetened condensed milk.

Sweetened Condensed Milk. Schematic flow diagrams for the manufacture of sweetened condensed milk are given in Fig. Co 4. The manner of preheating the milk to be condensed and of adding the sugar has a great effect on the quality of the finished product, influencing the bacteriological standard and the very important property of viscosity. As will be seen when the cooling of sweetened condensed milk is considered, finely crystallised lactose must be kept in suspension in the finished condensed milk and therefore a viscosity adequate for this purpose is required. Sweetened condensed milk is liable to a deterioration on storage known as " age-thickening " which is influenced by a number of factors. The milk in a period of from a few weeks to 3 to 4 years sets up to a stiff jelly which is insoluble in hot water and darkened in colour. A stable viscosity is thus an essential property of a first-class product, which should have a smooth free-flowing body, with a viscosity between 15 and 100 poises when freshly made.

The stability of condensed milk towards age-thickening seems to be influenced by a number of factors, and exhibits seasonal variations with a fairly regular unstable period beginning abruptly in April or May and ceasing in June, followed sometimes by a recurrence in less acute form in the autumn.[4] In this matter there is some conflict of opinion, but the main points appear to be:

(*a*) Stability is influenced by the " salt-balance " of the milk, that is, the balance of calcium and magnesium bases against phosphate and citrate radicles. This balance varies seasonally. In Britain an excessive calcium balance is most usual, and unstable milk may often be corrected by the addition of a small quantity of sodium citrate (approx. 2 oz. per 1000 lb. of raw milk) to the milk before preheating. If the milk is already stable, any addition of sodium citrate, disodium phosphate, or calcium acetate does not stabilise the milk any further; indeed, the addition of the last two to finished condensed milk promotes much increased thickening. This particular factor is of much greater significance in the case of evaporated milk. The feeding of silage may lead to increased viscosity and age-thickening.

(*b*) A high albumin + globulin content may have a marked effect. This is associated with colostrum and early lactation milk, and with mastitis milk. In the author's opinion the major difficulty in Britain arises from milk supplies containing a high proportion of milk from newly-calved cows.

(*c*) High developed acidity encourages age-thickening, particularly if the milk is already unstable for other reasons. A change of only 0·1 *p*H has a marked effect upon an unstable milk, but very little upon a stable one. The addition of sodium bicarbonate (2 to 4 oz. per 1000 lb. milk) is sometimes practised to reduce acidity. This improves subsequent stability, but rarely yields a high quality product. Stability is not correlated with changes in electrical conductivity.

(*d*) The preheating temperature is a major factor which is within the control of the manufacturer. Low temperature heating within the range 140° to 150° F. tends to yield a final product which thickens rapidly. As the temperature is raised, thickening is reduced, and the best results are usually obtained by preheating at 173° to 175° F. for 15 min. During periods of instability the optimum temperature is about 5° lower. Temperatures between 180° and 212° F. produce renewed instability, but this is then followed by another stable range, particularly between 225° and 248° F. On the Continent, high temperature preheating above 230° F. is not uncommon, using pressure vessels or specially designed tubular heaters, but this method has not been widely adopted in Britain. In practice, accurate temperature control is vitally important.

(*e*) It has been claimed that addition of the sugar in the form of a concentrated syrup gives a less viscous product than direct solution of the sugar in the milk, particularly if the sugar is drawn into the vacuum pan separately so that it mixes with milk only at a low temperature. The evidence for this seems rather uncertain, but there is no doubt that the syrup method has bacteriological advantages.

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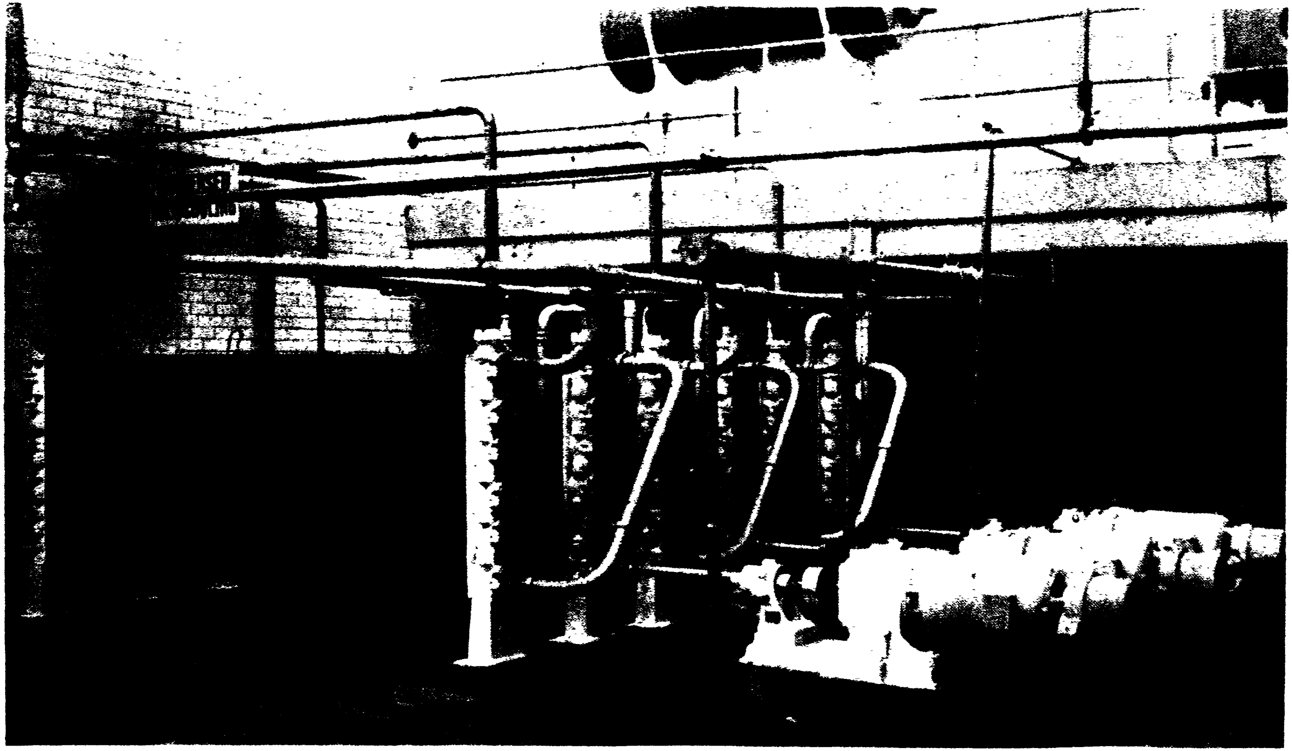
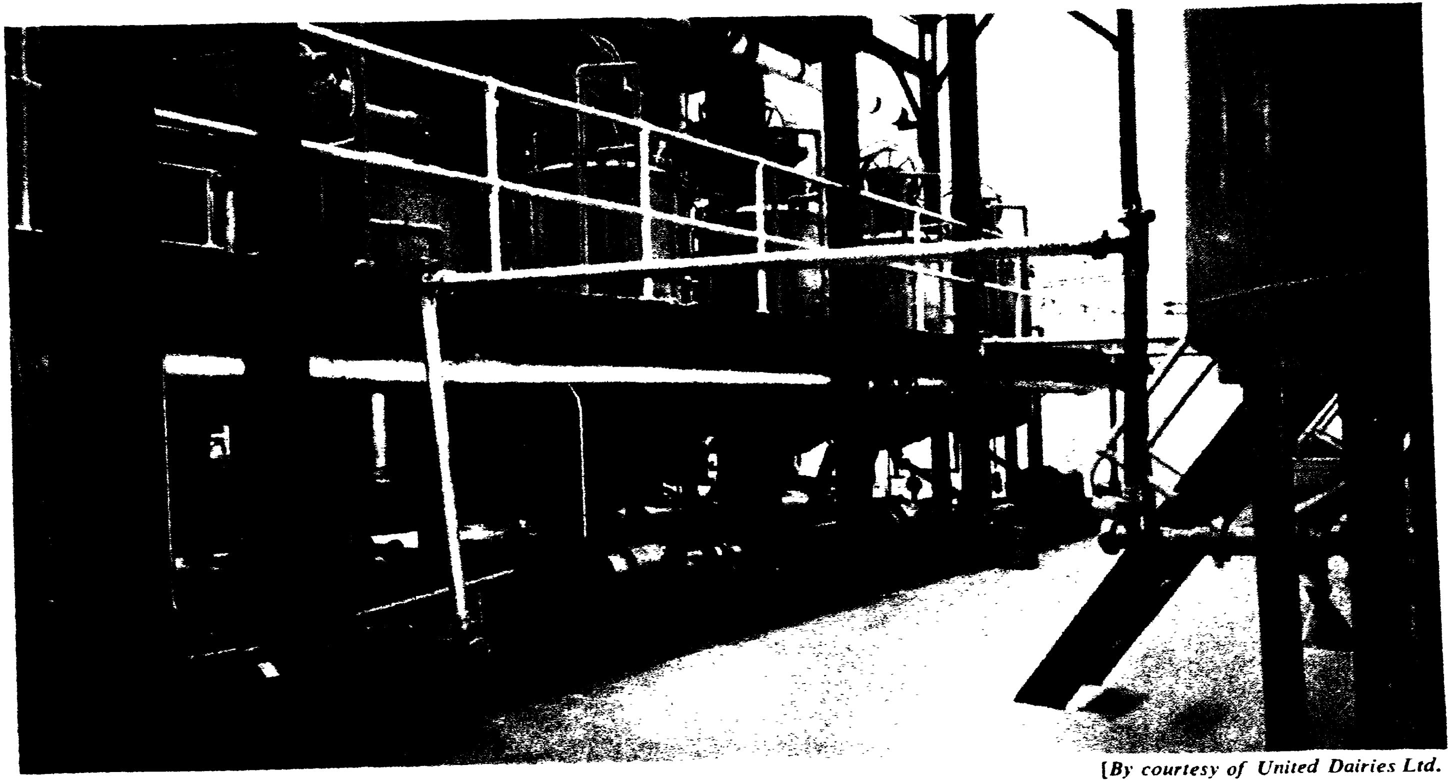
[4] Stebnitz and Summer (1935), *JDS*, **18**, 757.



[*By courtesy of Robert Morton Ltd.*

Fig. Co 5.—*Cooling Battery* 500 *to* 600 *gal. per hr. Sweetened Condensed Milk, with Variable Speed Morton Rotary Pumps.*



[By courtesy of United Dairies Ltd.

FIG. Co 6.—*Bulk Coolers.*

(*f*) Viscosity is influenced by degree of concentration, hence it is desirable to work closely to the legal standards. During unstable periods it is advisable to maintain a minimum content of solids-not-fat and to increase the sucrose content.

(*g*) The effect of storage temperature is very marked above 20° C., and increased viscosity is directly correlated with increased temperature and time of storage.

(*h*) Age-thickening is encouraged by the presence of invert sugar.

(*i*) Contrary to widely-held beliefs, there is probably no correlation between the alcohol test and development of age thickening. Indeed, there is no reliable routine test which can be applied to raw milk supplies. Nevertheless, by careful observation during the known difficult period, the first signs of increasing viscosity are detectable and appropriate measures can be introduced the next day (i.e. lower preheating temperature or addition of sodium citrate).

The best granulated cane or beet sugar must be used in the manufacture of sweetened condensed milk. Sugar which has been stored under damp conditions or which contains invert sugar is liable to ferment if contamination of the condensed milk with yeast should occur. The sugar-in-water concentration of the finished condensed milk, that is, $\frac{\%\ \text{sucrose}}{\%\ \text{sucrose} + \%\ \text{water}} \times 100$ should be at least 60 giving an osmotic pressure of 140 atmospheres which is sufficient to inhibit bacterial growth. A common practice is to add 1·4 × weight of milk solids (the " sugar ratio "); this usually requires 15 to 17 lb. sugar per 100 lb. milk. The sugar-in-water concentration should never exceed 65 per cent. The sucrose can be dissolved in the hot milk but is best drawn into the pan in the form of a concentrated solution in water. Although this water has to be evaporated in the pan, the method allows the solution to be rendered almost sterile by heating to 190° F. after which it can be filtered or clarified and drawn into the pan when desired.

At a temperature of 120° F. the water remaining in sweetened condensed milk is a saturated solution of lactose and also contains a high concentration of sucrose which appreciably affects the solubility of lactose. As the condensed milk cools the lactose solution becomes supersaturated and crystallisation will eventually occur. If special precautions are not taken, a relatively small number of crystalline nuclei will form and these will grow into crystals of macroscopic size which are hard and rough on the palate and are well described as " sandy " milk. Cooling must therefore be carried out under conditions which encourage rapid crystallisation of the lactose and hence the formation of very small crystals. The process of cooling sweetened condensed milk consists in producing a state of supersaturation of lactose in water by reducing the temperature to 85° to 90° F. and inducing mass crystallisation of the lactose by introducing finely divided lactose either as a powder or in the form of well crystallised condensed milk. After seeding, the condensed milk is agitated at this temperature before cooling to 60° F. The crystallisation of the lactose is complete in about 3 hr. and is accompanied by a distinct fall in the viscosity of the condensed milk. Hunziker [2] gives 10 microns as the mean crystal size in high quality sweetened condensed milk of normal viscosity, greater crystal size will give a mealy or sandy texture with sedimentation. The presence of sucrose does not greatly affect the crystalline form of lactose which is a truncated pyramid and only with high sucrose and total solids in the condensed milk is there any tendency for sucrose crystallisation to occur.

The cooling of sweetened condensed milk is carried out either in bulk coolers or by tubular coolers fed from a " drop " tank (Figs. Co 5 and 6). If the plant arrangement allows, the vacuum pan is emptied by gravity into the bulk coolers or drop tank. Otherwise these vessels are best filled by evacuating them and drawing in the condensed milk from the pan. The use of pumps for the purpose is usually unsatisfactory bacteriologically. Bulk coolers may be horizontal cylindrical vessels, fitted with a shaft through the horizontal axis carrying a tubular water-cooled spiral coil which also rotates and serves as an agitator. The cooling process should be carried out *in vacuo* to prevent the incorporation of air in the condensed milk by the agitator. The temperature of the milk is quickly reduced to 85° to 90° F. when the water is turned off, the seeding material added and the agitation continued for 1 hr. At the end of this period the water is again turned on and the temperature of the condensed milk reduced to 60° F., the agitation being continued for a further hour. Unless the shaft bearings of bulk coolers are designed so that no contamination with condensed milk can take place, they must be readily available for cleaning in order to avoid bacteriological contamination of the condensed milk. The bulk of the coil makes cleaning of the cooler somewhat difficult and air locks in the water circulation can be a source of trouble. Alternatively, a jacketed vat may be used. This comprises a vertical cylindrical vessel, fitted with a cooling water jacket and a vertical agitator fitted with scraper blades for the sides of the vat. The agitator mixes the milk and also keeps the sides of the vat clean. This type is easier to clean than the horizontal coil vat, and also possesses the advantage that the agitator shaft bearing, being mounted above the vat, is not in contact with the milk. The jacketed vat has been popular in Britain, but is now tending to disappear in favour of the continuous tubular cooler.

In the tubular cooler, the condensed milk is pumped through a long series of water-cooled tubes, the water flow being in the opposite direction to that of the condensed milk. The cooler is fed by a high pressure pump from the drop tank and will cool a large quantity of condensed milk before cleaning out is necessary. The cooler provides its own seeding material in the shape of a layer of crystalline lactose which builds up in the tubes and eventually reduces the bore of the tubes so as to restrict the flow of condensed milk and lower the rate of heat transfer to a point where the cooler must be drained out, cleaned, and sterilised to restore its efficiency. During a run when 50 tons of condensed milk can be cooled, the inlet to the feed pump and the cooler outlet are blanked off after the day's work and the cooler remains full of milk. Pressures up to 800 lb. to the sq. in. are required to start the milk flowing, when the cooler is once more joined up and cooling recommences. The cooler feed pump packings should be changed daily and the pump dismantled and cleaned at the same time as the cooler. After the tubular cooler has been cleaned out, the seeding material must be restored and this can conveniently be done by filling the cooler with well crystallised condensed milk and allowing to stand overnight. For this reason it is convenient to install two tubular coolers so that one is in operation while the other is cleaned and the seeding material is readily available. If this method is employed, careful bacteriological control is essential as any infection in one cooler will be passed on to the other. If any unsatisfactory condition arises, both coolers must be drained out, cleaned and sterilised, and restarted with lactose, which should be pure and finely powdered and can, with advantage, be sealed up in condensed milk cans and sterilised by heating for 2 hr. in steam at 5 lb. pressure before use. The last milk of the final batch of the day is circulated through the cooler by means of a by-pass from the cooler outlet to the drop tank inlet. When reseeding a clean cooler by means of lactose powder, a batch of milk is circulated through the cooler by means of this by-pass for 2 hr. and the powdered lactose sprinkled into the drop tank at intervals. The results obtained from the tubular cooler depend on proper control of the water flow and the speed at which the milk is pumped through the cooler. Satisfactory results can be obtained by reducing the temperature of the condensed milk to 60° F. in the time it takes it to pass through the cooler and the crystallisation will complete itself in the storage tanks without further agitation. For the best results, condensed milk should be cooled to 90° F. in a tubular cooler from which it passes into an agitator tank. After holding in this tank for some time the cooling is completed through a second series of water-cooled tubes. The tubular cooler gives a continuous flow, is reasonably simple, and in practice both crystallisation and bacteriological results are normally satisfactory.

A later type of batch cooler, known as the vacuum cooler, is also coming into use although its initial cost is rather high. This consists of a large vacuum pan fitted with an agitator, but no heating coils or jacket. The cooler is exhausted to a very high vacuum (about 29·5 in.) and the whole batch of finished milk at about 120° F. is drawn into it directly from the evaporator. The milk boils vigorously under the low vacuum and the resultant evaporation of water causes rapid cooling. The milk cools to 90° F. in about 20 min., is then seeded with lactose and agitated at 85° to 90° for 30 min., and cooled to about 70° F. in a further 20 min. The additional concentration of the milk during cooling must be allowed for, either by equivalent under-concentration in the vacuum evaporator or by permitting over-concentration and adding back the requisite quantity of water.

The cooled condensed milk is run into bulk storage tanks which feed the can fillers. At this stage the composition of the product is checked before canning, and adjustments are made if necessary. Storage tanks holding several batches are not uncommon, but single batch tanks are preferable. Pipelines carrying cold condensed milk should never be less than 3 in. in diameter and rotary positive pumps are always used. It may be just possible to secure flow to the can fillers by gravity alone.

Can fillers are usually of a plunger type delivering a fixed quantity of condensed milk. The cans themselves are standard open top "sanitary type" with a double seamed cover. Large scale producers of condensed milk frequently manufacture their own cans, but this is not economic for small to medium outputs. The cans are handled entirely by conveyors, which deliver empty cans to the fillers, then pass the filled cans to the lid seamer, the labeller, and finally to store.

The canning of sweetened condensed milk is carried out in an air-conditioned room to prevent contamination with mould (Fig. Co 7). The empty cans and the covers are sterilised by means of gas flames or jets of superheated steam shortly before filling, and the cans are filled as completely as possible in order to reduce the air space above the condensed milk to a minimum. For the confectionery trade, sweetened condensed milk is filled into barrels holding 4 to 6 cwt. of milk. The barrels should be of oak or beech and the use of second-hand barrels which have been used for edible fats is possible provided the heads of such barrels are removed and the cleaning out is very thorough. After steaming out, the cleaned barrels can be stored with a small amount of sodium sulphite solution in them provided they are again washed and steamed before use.

The high sugar concentration inhibits growth of bacteria, although their enzymes may remain active. Certain species of yeasts and moulds are, however, able to multiply in condensed milk and cause deterioration; the former may produce a gassy fermentation, whilst the latter produce lipolytic rancidity, cheesy flavours, and various indeterminate off-flavours. It should be remembered that the milk entering the evaporator contains few bacteria and no yeasts and moulds, and it is not difficult to maintain this condition throughout evaporation and cooling. The can filling and seaming process is the major source of contamination, and very close attention to cleansing and sterilisation of the machines is a very vital necessity, though involving numerous difficulties.

The colony count on yeastrel milk agar (4 days at 30° C.) should not exceed 500 per g. Coliform organisms are a further useful index of plant contamination and should be absent from 5 g. of condensed milk. Yeasts and moulds should be absent, but if present their ability to grow in high sugar concentrations is the significant consideration. These organisms may be estimated by direct plating on to beer wort agar or malt agar at pH 3·5 (B.S.I. Spec. 895 *Microbiological Examination of Butter* is suitable). For accurate work requiring detection of very small numbers, heavy inoculations into suitable liquid media may be employed.

Refs.: "The Microbiology of Sweetened Condensed Milk". Crossley, E. L. *I.D.C.* (1949), **2,** 438.

Evaporated (Unsweetened Condensed) Milk. The chemical composition of the raw milk is standardised as for sweetened condensed milk. It is then preheated, evaporated, homogenised, canned, and sterilised. In contrast to condensed milk, keeping quality depends upon production of a sterile product by heating the sealed cans at temperatures above 212° F. The choice of temperature treatment is influenced by considerations of heat stability of the product in addition to the bacteriological requirements. All the albumin is coagulated, and at high temperatures some heat coagulation of casein also occurs. In heat stable milks casein coagulation is only slight and serves to increase the viscosity of the product, but unstable milks yield curdy lumps which render the product unmarketable. Heat coagulation is influenced by (*a*) salt balance, (*b*) preheating temperature, (*c*) developed acidity, (*d*) degree of concentration, (*e*) sterilising temperature.

Preheating differs from that employed for condensed milk, since heat stability during subsequent sterilisation is improved by high preheating temperatures. Normally preheating is carried out at 203° F. for 10 min., but much recent work has been done on the stabilising effect of very high preheating temperatures and the use of base exchange methods to change the nature and concentration of the ions present.

Whole milk preheated to temperatures between 230° and 300° F. and held for the optimum time for that milk (½ to 5 min.) exhibits much greater heat stability after concentration to 26 per cent. solids and higher than do samples of the same milk preheated to 203° F. for 10 min. Acidity and stabilising salts have little effect. A good grade of milk preheated to 248° F. and held for 3 to 4 min. gives good results.[9]

There is no difference in heat stability between hard and soft curd milks, and mastitis milk reacts in the opposite manner to normal milk in every way.[10]

Developed acidity reduces heat stability and may be combated by addition of sodium bicarbonate as for condensed milk. This method produces a brown colour in the finished product and is now rarely used.

The preheated milk is evaporated in a vacuum pan as for condensed milk. The concentrated product is, however, less viscous and determination of the "striking point" by hydrometer is more accurate. Over-concentration reduces heat stability and coagulation is extremely likely if the content of solids exceeds 34 to 35 per cent. (Concentrated milk coagulates at a lower temperature than does the original raw milk, the effect increasing with the degree of concentration.)

Homogenisation is necessary to prevent fat separation during sterilisation and to improve viscosity. This process is carried out on the concentrated milk as it leaves the evaporator at 110° to 120° F. Homogenisation tends to reduce heat stability and the minimum pressure (found by trial) should be used; two-stage machines are employed at pressures varying from 1800 to 2500 lb. per sq. in. If the milk cannot be canned immediately in continuous flow it must be rapidly cooled. Fig. Co 8.

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[9] Webb, Bell, Deysher and Holm (1943), *JDS*, **26**, 571.
[10] Welch and Doan (1935), *JDS*, **18**, 287.

Instability due to salt balance, commonest in the spring and late autumn, may be corrected by addition of sodium citrate stabiliser at this stage to the concentrated milk. The most desirable addition may be determined by preparing pilot experimental batches which are heated at the sterilising temperature.

The sterilising process consists of three stages, " coming-up ", holding, and cooling (Fig. Co 9). During the " coming-up " stage, a steady and even rise of temperature is necessary so that at the end of a given time it is known that the whole of the can contents will have reached the desired temperature. This temperature is maintained during the holding stage, after which rapid cooling is necessary in order to preserve the colour, flavour, and texture of the milk. In the intermittent or batch steriliser, the cans are placed into metal crates which are loaded into a rotating frame inside the steriliser shell. After loading, the steriliser is partly filled with hot water (about 130° F.) to such a depth that the cans in the lowest part of the rotor are submerged. The " coming-up " time should be about 18 min. and, as the rate of rise of temperature per min. will depend on the initial temperature of the steriliser and the desired holding temperature, it is useful to have a chart which can be followed if hand control of the steam is employed. Automatic control is used to maintain a steady temperature during the holding stage. The speed of the rotor should be 10 to 12 r.p.m. during the " coming-up " stage and for the first 2 min. of the holding stage, after which it is slowed down to about half this speed and increased to 15 r.p.m. during the cooling stage. The air vent on the top of the steriliser should be kept open until boiling-point is reached and at the end of the holding stage, before the cooling water is turned on, the hot water can be blown out of the steriliser into an insulated tank by the steam pressure and can be used for the next batch. For good results, careful attention should be paid to the distribution of the steam and cooling water pipes in the steriliser so that an even rise or fall of temperature is obtained in all parts. A stable milk will withstand a sterilising temperature of 235° to 240° F. for 15 to 18 min. and a check on this by means of a pilot steriliser serves as a useful guide. Compressed air may be introduced into the steriliser at the beginning of the cooling stage to equalise the internal pressure in the cans and lessen the strain on the can seams. The use of a sterile chlorinated water for cooling is highly advisable, as some cans tend to draw in a small amount of water at this stage and contamination with non-sterile water would result in spoilage.

The continuous steriliser consists of three vessels in which the three stages are carried out. The cans pass through each vessel in turn on a rotating spiral trackway and are transferred mechanically from one stage to the next. The speed and temperature control of the steriliser can be regulated to suit different sizes of cans.

The cans should be cooled to about 85° F. in 15 min. and withdrawn from the steriliser whilst they retain sufficient heat to dry off.

Automatic continuous sterilisers, suitable only for very large and regular outputs, are fundamentally similar to those used for production of sterilised milk in bottles, and comprise a pressure steam chamber with a water seal on either side. The cans are raised gradually to sterilising temperature, held, and cooled to 85° to 90° F. Treatment time is determined by the rate of passage through the machine, which can be varied for different can sizes. The cans roll along a spiral trackway, with mechanical transfer between stages.

Evaporated milk should be sterile, but small numbers of heat resistant spores may survive in a small proportion of cans; many of these remain dormant and have no effect upon the product. The most deleterious types in Britain are certain strains of *B. subtilis* and *B. licheniformis* which may withstand treatments up to 248° F. for 20 min. Some strains remain dormant, but others develop and produce a very bitter flavour with noticeable thinning of the milk. The mere presence of the organisms gives little information, and no laboratory method of distinguishing harmless and active strains is known; hence it is also necessary to incubate cans and examine them for flavour and consistency. Acid curdling due to *B. coagulans* and sweet curdling due to *B. cereus* (see also Sterilised milk) may occur, though not commonly in Britain; these organisms form less resistant spores than those of *B. subtilis* and their presence suggests underheating. Anaerobic spore-forming bacilli, which produce blown cans, cause little trouble in Britain. If a spore-forming flora is found, it becomes necessary to check not only the sterilising time and temperature, but also the number of spores present in the raw milk supply and at all stages *prior* to sterilisation. In addition, non-spore-forming organisms present in the cooling water or the atmosphere may be drawn into faulty cans. These are mainly micrococci, which produce acid curdling, and coliform organisms, which produce acid curdling with blowing of the can. In practice, the majority of defective cans are due to faulty sealing. Regular checking of can seams is of great importance (can manufacturers supply gauges for this purpose). Obviously, any scheme of bacteriological control must include differentiation of spore-forming and non-spore-forming organisms.

Since the number of surviving organisms, if any, is very small, the normal colony count methods are valueless if applied to the freshly-made product. If early information is required, it is essential to inoculate large quantities of the evaporated milk into several tubes of a liquid enrichment medium such as bromcresol purple milk or glucose broth. When more time is available, representative cans may be incubated for 10 to 14 days at 30° to 32° C. The incubated cans are then examined by inoculation of 1 ml. quantities into the liquid media above, or by plating 1 ml. quantities with yeastrel milk agar, and incubating at 30° C. for 3 to 4 days. The plates are likely either to be sterile or to show large numbers of colonies. Since a large proportion of cans is probably sterile, stringent aseptic precautions must be observed. Nevertheless, it must be remembered that each can is largely an independent unit and not necessarily representative of the whole batch; this is invariably so in the case of can leakages.

The safest procedure is to combine the bacteriological examination with incubation of the *whole batch* in a hot room maintained at about 85° to 90° F., for not less than 14 days. Each can is then subjected to individual inspection. Blown cans are obvious, whilst either curdling or thinning is detectable by shaking the can. The sound cans are then released for distribution. If provision of the space and labour involved is quite impracticable, a reasonably good alternative is to select a fixed proportion of each batch (not less than 1 per cent.) for incubation. After 7 to 10 days a few cans can be withdrawn for bacteriological examination, the result of which is known when the incubated cans are due for inspection after 14 days.

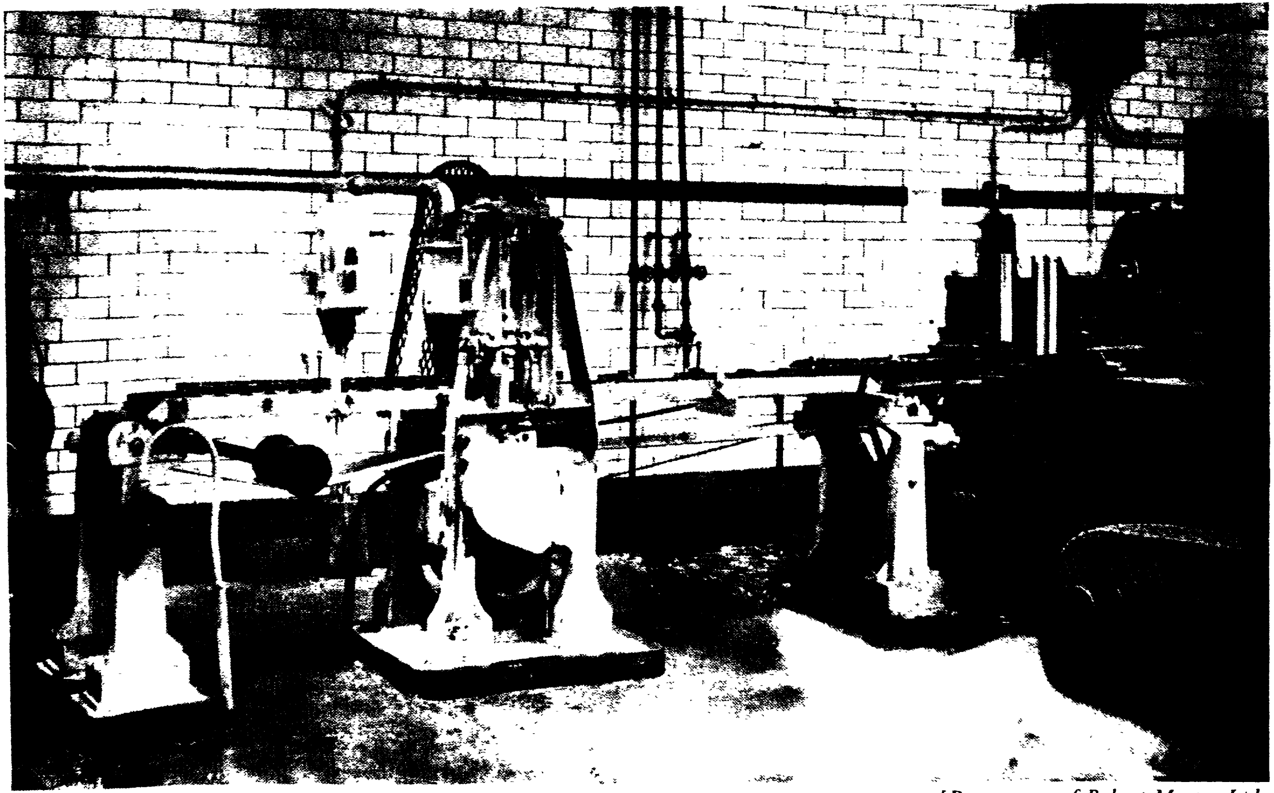
The development of an intensely bitter flavour accompanied by a large drop in the viscosity is due to aerobic spore-forming bacteria of the subtilis type.[11]

It has been shown that the heat resistance of bacterial spores is maximum when the spores are formed at the optimum growth temperature for the species, and there is no essential difference between moist and freshly dried spores in this respect.[12]

When equal quantities of unsweetened condensed milk and bromcresol purple indicator are mixed, the formation of an olive-green colour indicates developing acidity and hence doubtful keeping quality when the milk has been canned for several weeks and stored at atmospheric temperature. The formation of crystalline deposits of calcium citrate in the can is due to storage of the milk at temperatures above 60° F.

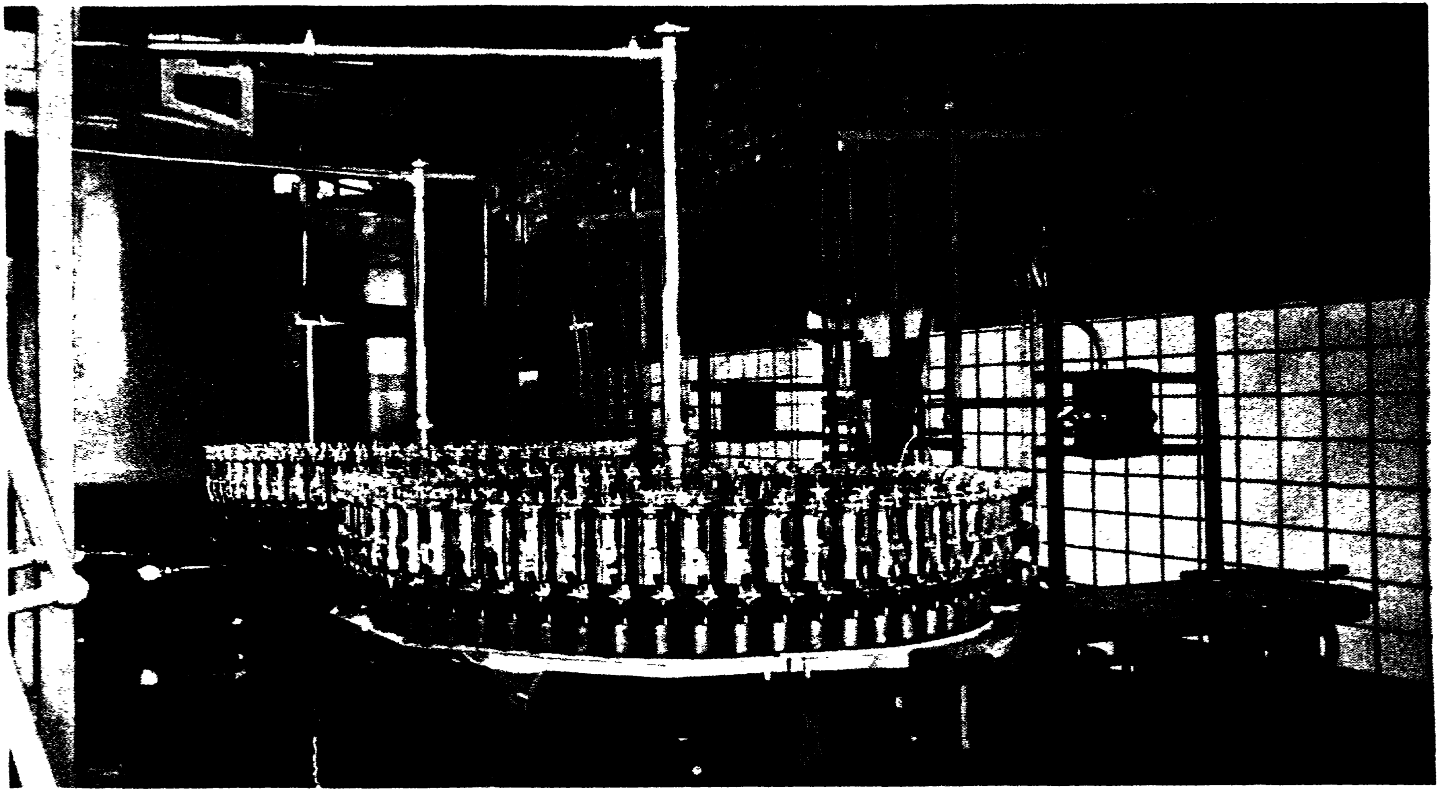
[11] Nichols (1939), *JDR*, **10**, 231.

[12] Theophilus and Hammer (1938), *Res. Bull. Ia. Agric. Exp. Sta.*, 224.



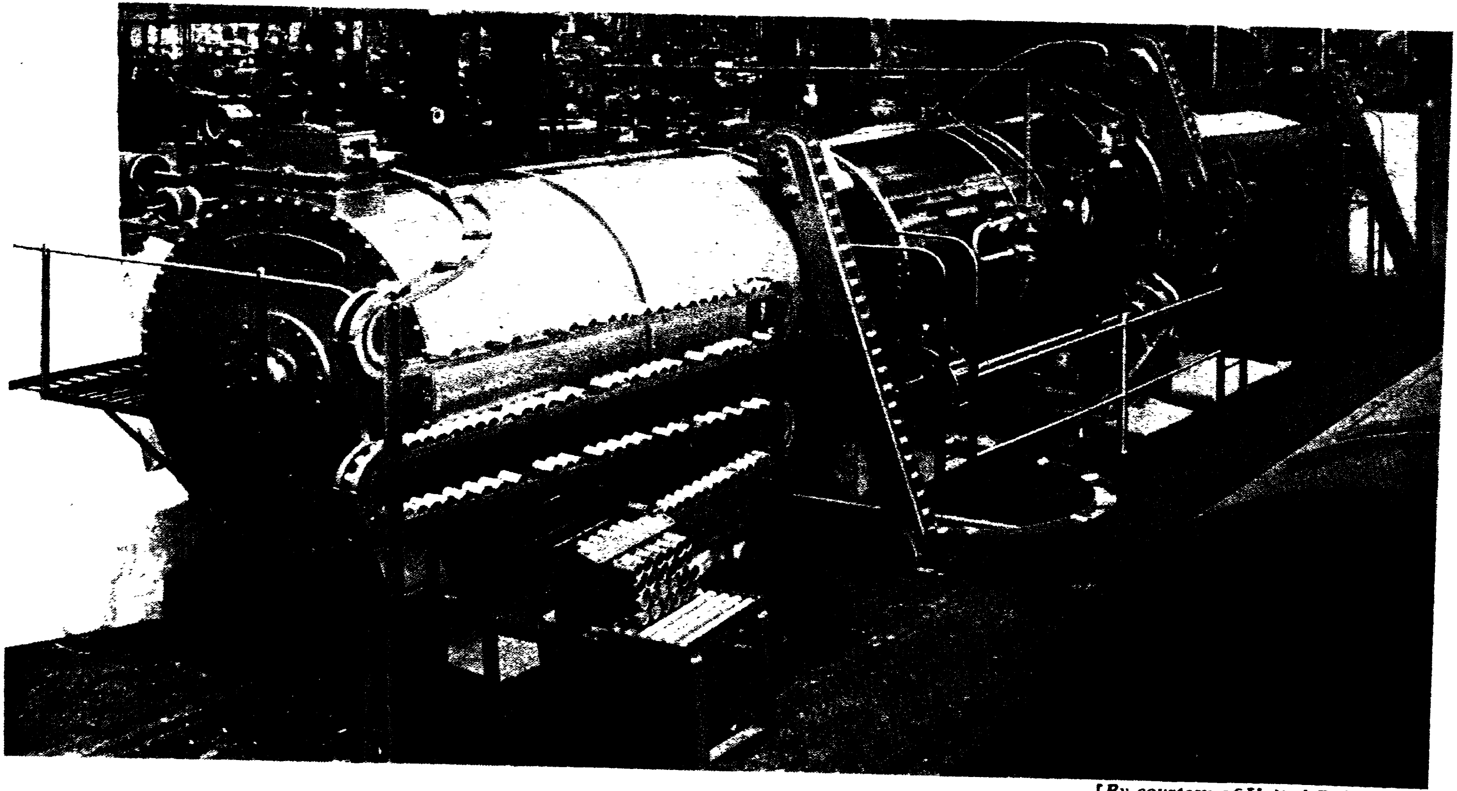
[By courtesy of Robert Morton Ltd.

FIG. Co 7.—" *Morton* " *Sweetened Condensed Milk Can Filling Machine, 82 cans per min.*



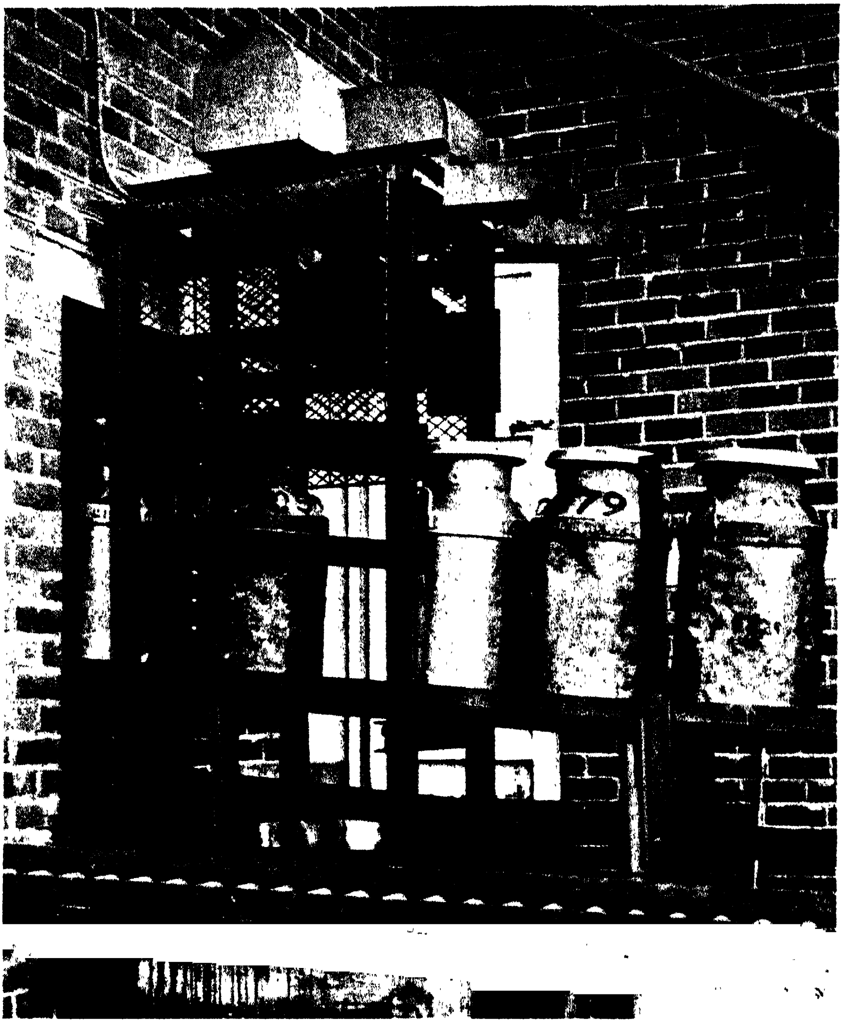
[By courtesy of United Dairies Ltd.

FIG. Co 8.—*Filling Evaporated Milk into Tins.*



[By courtesy of United Dairies Ltd.

FIG. Co 9.—*Heating, Holding, and Cooling Tins of Evaporated Milk.*



[*By courtesy of Wright-Hargreaves Ltd.*

FIG. Cn 1.—*Can Conveyor with Lid Lifting Device.*

Methods for the chemical analysis of sweetened and unsweetened condensed milk have been published as the following reports of the Milk Products Sub-committee to the Standing Committee on Uniformity of Analytical Methods of the Society of Public Analysts:

" Method for Fat in Sweetened and Unsweetened Condensed Milk ", A (1927), **52**, 402; " Method for Sucrose in Sweetened Condensed Milk ", A (1930), **55**, 111; " Method for Total Solids in Sweetened and Unsweetened Condensed Milk ", A (1932), **57**, 630.

These methods are described in Richmond's *Dairy Chemistry*.[3]

See Coliforms; Management of Creameries; Media; Prices; Stability; World production.

Refs.: B.S. 1742 (1951) (chemical analysis); Deysher and Webb (1952), *JDS*, **35**, 106 (deposit in evap.); Webb *et al.* (1951), *JDS*, **34**, 1111 (storage temperatures); Schulz and Reineke (1949), *M*, **4**, 138 (evaporators); Hawley (1947), *SAB*, p. 1 (bacteriology); Kieferle and Seuss (1949), *IDC*, **1**, 155 (effect silage); van Kreveld (1949), *IDC*, **2**, 44 (sweet curdling); Torssell *et al.* (1949), *IDC*, **2**, 246 (viscosity and conductivity).

CONDENSED WHEY. *See* Whey.

CONDENSERS. *See* Condensed milk.

CONDUCTIVITY OF MILK. This varies from about 30 to about 50×10^{-4} mhos, according to breed, age, state of lactation, etc., and is increased by mastitis or udder disease. The sodium chloride accounts for about 75 per cent. of the total conductivity. *See* Abnormal milk; Chloride; Rapid abnormality indicator.

CONFECTIONERY, DAIRY PRODUCTS IN.

Ref.: Whittier and Webb.

CONFORMATION. *See* Breeding.

CONSTANTS.

	Value	*Logarithm*
Π	3·1416	0·4972
Π^2	9·8696	0·9943
$\sqrt{\Pi}$	1·7725	0·2486
Atmospheric pressure . . .	14 68 lb. per in.^{2}	1·1667
Atmospheric pressure . . .	33·81 ft. water	1·5290
Atmospheric pressure . . .	29·9 in. mercury.	$\underline{1}$·4757
Density of air	0·0807 lb. per ft.^{3}	2·9069
Density of water . . .	62·43 lb. per ft.^{3}	1·7954
Density of cast iron . . .	c. 450 lb. per ft.^{3}	2·65
Density of steel . . .	c. 490 lb. per ft.^{3}	$\underline{2}$·69
Coefficient of cubical expansion of air	0·003665 per ° C.	$\underline{3}$·5641
Coefficient of cubical expansion of water	0·00018 per ° C.	$\underline{4}$·2553
Coefficient of linear expansion of steel	$11·1 \times 10^{6}$ per ° C.	5·0453

Refs.: Kaye and Laby (1948), *Tables of Physical and Chemical Constants*, London; *Handbook of Chemistry and Physics* (1949), Cleveland, Ohio. *See* Weights and measures.

CONSTITUENTS OF MILK. Milk contains about 87·6 per cent. water, 4·8 per cent. lactose, 3·7 per cent. fat, 3·0 per cent. protein, 0·75 per cent. ash, and small amounts of other substances. The detailed constituents are as follows (figures are percentages):

(1) **Fat Phase.** Butter fat consisting of the glyceryl esters of fatty acids of the following approximate composition:

Butyric acid . . .	3·0	Palmitic acid . . .	25
Caproic acid . . .	1·6	Stearic acid . . .	4 to 8
Caprylic acid . . .	1·3	Arachidic acid . . .	1
Capric acid . . .	3·0	Oleic acid . . .	30 to 39
Lauric acid . . .	3 to 6	Linoleic acid* . . .	3
Myristic acid . . .	6 to 16		

Dihydroxystearic and linolenic acids may be present in traces.

* Essential to life under certain conditions.

Lipoids, etc. Lecithin 0·04, cephalin, carotene, and carotenoids, cholesterol and ergosterol, vitamin A,* vitamin D,* vitamin E.*

(2) **Colloidal Phases.** Casein 2·6 (colloidal suspension) and albumin 0·4 and globulin 0·15 (colloidal solution). These proteins are composed of amino acids, etc., the percentages being approximately as follows:

	Casein	*Albumin*
Glutamic acid	22	11·5
Hydroxyglutamic acid	0	10
Leucine	12	16·5
Proline*	8	4
Valine	7·5	2
Lysine*	7	9
Tyrosine*	6·4	1·5
Arginine	4·5	3
Phenylalanine	3·9	2
Histidine*	3·7	2
Aspartic acid	4·1	5
Tryptophane*	1·4	2·5
Alanine	5·6	2·5
Ammonia	1·5	1·5
Dodecano amino acid	0·75	?
Serine	5·2	2
Glycine	0·4	0·4
Methionine*	3·2	?
Cystine*	0·4	3
Hydroxyproline	2·1	?
Threonine	3·5	
Iso-leucine	1·4	
Phosphoric acid	2·7	
Galactose	0·3	

Casein contains 0·85 per cent. phosphorus in the protein molecule. Note the high content of cystine in albumin which is linked with the decomposition of this protein to hydrogen sulphide.

It has also been claimed that milk contains proteoses, lactomucin, and alcohol-soluble proteins.

Enzymes. These can be considered loosely to be in colloidal solution like albumin. Some, however, are associated with the cells, particularly catalase. The following are generally accepted as being present in normal milk.

Enzyme	*Acting on*	*To produce*
Diastase	Starch	Sugars
Lipase	Fats	Fatty acids + glycerol
Phosphatase	Organic phosphates	Free phosphate
Proteinase (the classical "galactase")	Proteins	Proteoses, peptides, and amino acids
Peroxidase	Peroxides	Active oxygen
Reductase	Oxidised form	Reduced form
Catalase	Hydrogen peroxide	Molecular oxygen

These enzymes vary considerably in amount and the cells and bacteria may contribute to the total. The presence of lactase (splitting lactose to dextrose and galactose) is very doubtful.

Salts in colloidal suspension. It is impossible to say precisely how much of any salt is in colloidal suspension but approximately 75 per cent. calcium, 20 per cent. magnesium, and 65 per cent. phosphates are non-diffusible.

(3) **True Solution.** ***Sugars.*** Lactose 4·8, possibly also dextrose (glucose).

Citric acid occurs to the extent of about 0·2 per cent.

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* Essential to life under certain conditions.

Mineral salts.

Cations	*Anions*
Potassium *	Phosphates *
Sodium *	Chlorides *
Calcium *	Sulphates
Magnesium *	Citrates
Zinc	Carbonates
Aluminium	
Copper *	
Iron *	
Manganese *	

Iodine, * silica and fluorine * also occur in traces.

Nitrogenous substances in traces. Creatine and creatinine ; urea ; thiocyanic acid ; hypoxanthine, xanthine, and uric acid ; choline, trimethylamine ; methyl guanidine.

Water soluble vitamins.

Vitamin B_1 * (aneurin or thiamine)

$$\text{Vitamin } B_2{}^{*}\left\{\begin{array}{l}\text{riboflavin}\\ \text{nicotinic acid}\\ \text{pantothenic acid}\end{array}\right.$$

Vitamin C * (ascorbic acid)

Dissolved gases. Carbon dioxide (milk in the udder contains 10 per cent. by volume) ; oxygen ; nitrogen.

Refs.: Davies; Richmond; Rogers. *See* Enzymes; Nutritive value; Vitamins; and individual constituents.

CONSUMPTION OF MILK AND MILK PRODUCTS. *See* Milk marketing; Nutritive value; Utilisation.

Refs.: Magee and Wright (1949), *IDC*, **4**, 310; Martin, 320; Ashby and Ashby, 363; Clark, 370; Juréen, 383; Bransby (1946), *JDR*, **14**, 354 and 369 (social classes); Walworth; Murray and Rutherford (1941), *Milk Consumption Habits: Preliminary Report*, Oxford; Murray (1937), *Milk Consumption*, Oxford; Crawford and Broadley.

CONTAGIOUS ABORTION. *See* Abortion; Diseases of dairy cattle.

CONTAMINATION. This term is used in the dairy industry in the sense of adding bacteria to milk or to utensils, plant, containers, etc. The avoidance of such contamination is of the first importance in dairying. *See* Bottle-washing; Cleaning; Clean milk production; Detergents; Dirty churns; Management of creameries, of pasteurising depots; Surface to volume ratio.

CONVECTION. The transfer of heat in fluids (liquids and gases) by upward and downward movement of the particles.

CONVERGENCE TEMPERATURE. That temperature at which the contents of the freezing-point tube of a cryoscope are in thermal equilibrium with the rest of the apparatus. *See* Freezing-point test.

CONVERSION TABLES. *See* Thermometric scales; Weights and measures.

CONVEYORS. (i) **For Churns.** These may take the form of roller conveyors slightly inclined so that gravity slowly moves the churns along, or sunk chain conveyors in the platform. Fig. Cn I shows a can conveyor with a lid-lifting device.

(ii) **For Bottles.** These are invariably of the chain type. *See* Bottle washing; Churn washing; Mechanical handling.

Ref.: B.S. 2075 (1954), (Chains and Wheels).

COOLING OF MILK. Failure to cool milk and failure to clean and sterilise utensils are easily the most important factors responsible for poor keeping quality in milk and the associated losses due to souring.

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* Essential to life under certain conditions.

COOLING OF MILK

It has been estimated that about 1 per cent. of the total milk supply was lost through souring in 1941. Moreover, from 5 to 10 per cent. of the producers in this country, regularly mix into the bulk milk of such high count that it seriously imperils the keeping quality of ordinary supplies. Milk souring is almost entirely a seasonal problem, and heat waves inevitably result in wholesale returns of milk to farmers (5 to 10 per cent. is by no means uncommon) and the souring of whole tanks of milk which may mean from 1000 to 3000 gal. at a time.

The considerable effect of temperature on bacterial growth is illustrated in the following table:

TABLE Ci I

Milk held at temperature ° F.	*Plate count per ml. after* 24 *hr.*
32	2,400
39	2,500
41	2,600
43	3,100
50	11,600
55	18,800
61	180,000
68	450,000
86	1,400,000,000
95	25,000,000,000

It will be seen that 55° F. is a critical temperature for milk; above this point temperature has a marked effect on bacterial growth and hence on keeping quality. The relation between count and keeping quality is shown in Table Ci II.

TABLE Ci II

(from Barkworth *et al.* (1929) J. Min. Agric. 170)

Plate count (at about 24 *hr.)*	*Keeping quality in hours at* 60° *F.*	
	Coli absent in 1 *ml*	*Coli present in* 1 *to* 1/1000 *ml.*
1,000	77	71
5,000	72	66
10,000	70	63
30,000	69	60
50,000	60	57
100,000	61	53
200,000	58	53
500,000	57	49
750,000	61	49
over 750,000	56	41

It has been estimated by one worker that clean milk will keep sweet for 7 days at 45° F., 3 days at 60° F., and 2 days at 70° F. Another states that milk produced under reasonably clean conditions and cooled to 70° F. will keep sweet for 24 hr., and that every degree of cooling below 70° F. will increase this time by 2 hr., while every degree *above* 70° F. means a corresponding loss in keeping quality.

We may summarise the evidence on this point by saying that it is highly desirable that milk should be cooled to 55° F. or lower, especially if ultimately destined for the distant liquid market.

In many districts the water supply to farms is a disgrace to the country, and often when the supply is good the temperature in summer is 65° to 70° F., and sometimes higher, so that it is of little use for cooling. It is obvious, therefore, that some special measure is necessary for the producton of milk of good commercial quality. Two methods are open to the farmer: making the best of simple homely methods, or the purchase of a farm refrigerating unit.

The simplest and most reliable method is to construct a hole or trough in the ground on the north side of a building and fill it with water to a depth of 18 to 24 in. There should be at least 50 gal. of water for each 10 gal of milk. In this way the water acts as a conductor of heat away from the churn of milk and the cooling capacity of the earth is drawn upon, as illustrated in Table Ci III.

With this method of cooling, it takes about 3 hr. for the temperature of the milk to get to within a degree or two of that of the water.

TABLE Ci III

Month	*Maximum temperature in hole (° F.)*	*Maximum atmospheric shade temperature (° F.)*
June	58	72
July	60	83
August	60	80
September	62	83

Refrigeration on the Farm. It will be evident from Table Ci I that milk should be cooled to 55° F. or less immediately after production, and the hotter the weather the more important it is to cool the milk on the farm. We may reasonably claim that in cold or moderate weather (mean atmospheric temperature below 55° F.) refrigeration on the farm is not essential, as the ordinary water cooling is adequate. In some areas only 15 per cent. of producers cool their milk in late autumn, winter, and spring, and not more than 25 per cent. use a proper cooler in summer. Probably about half make some attempt to cool milk by some method or other in hot weather in such areas. It may be asserted that refrigeration is essential in warm weather, *i.e.* when the mean atmospheric temperature is 55° F. or higher. This means, in effect, that special cooling must be carried out by the farmer from May to September, as indicated in Table Ci IV.

TABLE Ci IV

Month	*Mean atmospheric temperature* ° *C.*	° *F.*
January	5	41
February	5	41
March	7	44
April	9	48
May	13·5	56
June	15·5	60
July	17	64
August	16·5	63
September	15	59
October	11	52
November	7·5	45
December	5·5	42

Available methods of securing this special cooling may be classified as: (1) Surface evaporation methods designed to lower the temperature of the cooling water. (2) Complete refrigerating units for the farm. (3) Supplies of refrigerant (water ice or CO_2) for farms. (4) Refrigeration at small sub-depots.

Evaporation methods are bulky, clumsy, and not very effective for large quantities of warm liquids. The cooling effect obtained with small quantities of milk, *e.g.* 1 pint, tends to give a false idea of their value. If we assume that, even in hot weather, milk can always be cooled by the water available to 70° F., it is evident that we have to withdraw 15° F. at least from the milk. This is equivalent to a requirement of 100 gal. of water at 52° F. for 20 gal. of milk at 70° F., assuming that both milk and water finish at 55° F. Since water can be maintained at 60° F. by the method of Table Ci III, the problem is to subtract about 10° F. from say, 100 gal. of water at 60° F. Although this could probably be done by surface evaporation, it would require a fair amount of pumping.

It would probably be just as cheap in the long run to install a refrigerating plant.

Farm refrigerating units are practically never used, except by producer-retailers. The initial cost and servicing required do not, in practice, make it worth while for the average small-scale producer to install a refrigerating plant. However, quality payment and the introduction of a cheap, standard, mass-produced farm refrigerating unit would completely alter the position.

A system of supplying farms with ice or solid CO_2 has certain points in its favour. Lorries returning empty churns could readily deliver solid CO_2—water ice would be too bulky—manufactured at the creamery. A simple cabinet could be used at the farm, and the method would be simple and avoid all machinery on the farm. It is, however, expensive.

One method which might be adopted would be that of collection centres at one well-equipped farm in each area of, say, 1 mile radius. Each producer in this area would be required to deliver his milk immediately after production to this centre. Two methods are then available. Either his churns may be immersed in a chilling tank of water at 35° F., or the milk gallonage checked and then the milk run over a surface cooler with a brine section.

The dairy industry has in the past suffered from vague legislation. Thus it is of little use to insist on cooling milk to within 5° F. of the temperature of the water if the latter is at 70° F. or higher.

For creameries it is possible to insist on efficient cooling by legal means, and in the future we may anticipate that ability to cool all milk immediately to below 40° F. will be a *sine qua non* for all buyers.

Universal refrigeration on the farm would greatly diminish the load on the creamery refrigeration. In addition, the collecting and cooling sub-depot in the village would simplify collection.

The Surface Cooler versus Churn Immersion. Before establishing any national scheme for equipping dairy farms with proper facilities for cooling milk, it is obviously advisable to explore all possible methods for achieving this object. Broadly speaking, there are two methods. In the first the milk is poured from the carrying pail into a bowl from which it passes over a surface cooler which consists of a series of pipes through which water flows. If refrigeration is available the cooler has a lower section through which brine flows, or in some cases the lower section consists of a direct expansion unit. This method of cooling is practically universal in this country, but in America and in a few places in this country an entirely different system of cooling is practised—the churn immersion method. In this, the milk is poured from the carrying pail direct into the churn through the usual strainer. When the churn has been filled, it is lowered into a tank or trough of cooling water which may or may not be refrigerated. It is of the utmost practical importance to the dairy farmer that he should appreciate the advantages and disadvantages of these two methods of cooling milk, in order that he may have the facts at his disposal. Although the churn immersion method is comparatively rare in this country, it has been practised for over ten years so that it is not a novelty.

As the advantages and disadvantages of the surface cooler method are well known in the dairy industry, we may focus our attention on the churn immersion system and discuss the pros and cons of this method.

Advantages. As the surface cooler method is so well established, it may well be asked by the practical farmer why farmers should be asked to consider a new and apparently revolutionary method of cooling milk. The answer is that the churn immersion method possesses one tremendous advantage over the surface-cooler method. Namely, that there is no contamination of the milk in the churn immersion method. It has been established beyond all possible doubt that the two most important factors in clean milk production are the cleanliness and the sterility of the utensils, and efficient cooling of the milk. The old classical ideas about faecal contamination as the major cause of bacterial souring of milk are now obsolete and it is recognised that the biggest source of souring bacteria is the soured milk residues which persist in improperly cleaned utensils. Of all the equipment on the farm with which the new sweet milk comes into contact—milking pails, carrying pails, strainers, bowl, cooler, and churn—the two most frequent sources of worry are the cooler and the strainer. It is a not uncommon experience for dairy farm advisers to find appreciable amounts of souring milk residues on the coolers, especially in the spaces between the corrugations at the back of the cooler and inside the tap with which the flow of milk from the bowl is controlled. In addition, it is rare to find one of the brass gauze type of strainer which is free from milky residues. We shall not be far wrong therefore if we pronounce the ordinary type of surface cooler as one of the biggest menaces to the dairy farmer. Properly cleaned and sterilised it may be an invaluable friend to the milk producer; neglected, it can be a most insidious foe. Experiments have proved that the use of a dirty cooler can do more harm than good to milk, *i.e.* sweet milk cooled over a dirty cooler may, as a result, have a poorer keeping quality than if it had not been cooled at all. This particular advantage of the churn immersion method is so overwhelming that we must consider it as of preponderating importance in any discussion of the pros and cons of the two methods of cooling.

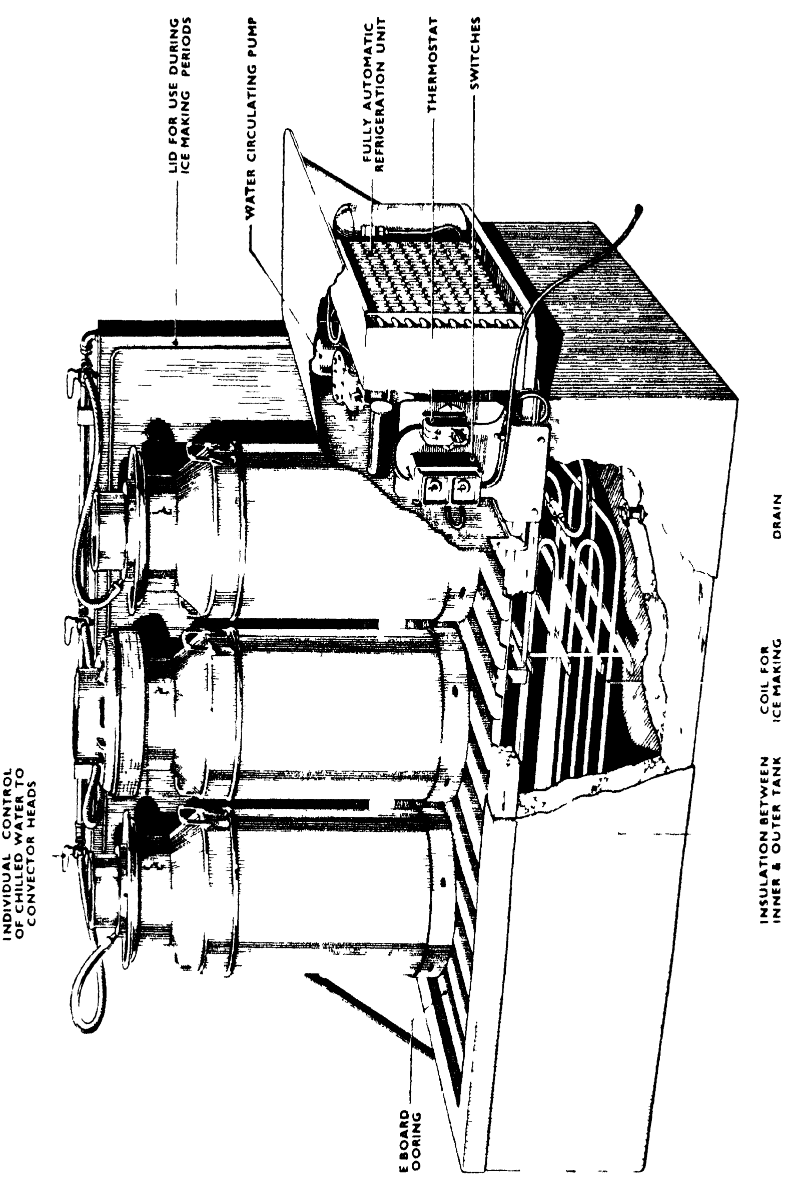
A second advantage which follows from the above is that the churn immersion method obviates the necessity for the cleaning and the sterilising of the cooler. With present labour difficulties this is a most important point.

A third advantage of this method is that the maximum use can be made of a limited supply of water. For example, it has been observed that cases where apparently good producers get trouble with their milk have often been correlated with the use of apparently clean but actually bacteriologically-dirty coolers, and a most inadequate water supply which is often not only warm but frequently badly contaminated with *B. coli* and other bacteria which have a drastic effect on the keeping quality of milk.

One sometimes finds milk producers deliberately passing the milk over the cooler at a very high rate, for the reason that the water will not last out if they allow it to trickle slowly as it should do. It is possible by careful control of the rate of flow to cool milk to within 1° F. of the temperature of the water, but a reasonable limit is within 3°. It is obvious that with water, say, at 65° F. and such a high rate of flow that the milk is only cooled down to within 5 or more degrees of the temperature of the water, the efficiency of cooling is far from what it should be. Further, if the water gains access to the milk through a leak in the cooler bad bacterial contamination can easily occur, and all farm advisers will be familiar with this as a not uncommon but particularly subtle trouble to track down. Moreover, there is, of course, the danger of water getting into the milk and so rendering the producer liable to prosecution.

In the churn immersion method it is necessary to have a tank or trough containing a large proportion of water to the amount of milk to be cooled. This proportion should be at least 5 : 1, *i.e.* at least 50 gal. for every 10-gal. churn to be cooled. The actual construction of the tank or trough is not important, but it should obviously be in a well-shaded spot, such as on the north side of a building or thick wall. The level of the water should be such that the churn can be lifted easily from the trough on to the lorry, and be so constructed that the farmer or driver can place his foot astride the trough and lift the churn with the weight distributed evenly on both legs. A block and tackle device makes this operation much easier. Further, provision should be made for running away the water at intervals by a suitable tap at the bottom of the trough.

It would be advisable to chlorinate the water from time to time as otherwise the water may get foul, especially as traces of milk may gain access. With proper control and chlorination it should not be necessary to renew the water more than


INDIVIDUAL CONTROL OF CHILLED WATER TO CONVECTOR HEADS
LID FOR USE DURING ICE MAKING PERIODS
WATER CIRCULATING PUMP
FULLY AUTOMATIC REFRIGERATION UNIT
THERMOSTAT
SWITCHES
E BOARD OORING
INSULATION BETWEEN INNER & OUTER TANK
COIL FOR ICE MAKING
DRAIN

[By courtesy of Gascoignes (Reading) Ltd

Fig C1 1 —*Rotorfreeze In-can Refrigerated Cooler* once a week or fortnight, and in this way a considerable economy in water is obtained, an important point on many farms. If chlorinated, the water should be kept pink to phenolphthalein by adding a little soda ash. Otherwise the chlorine may accelerate corrosion of the churns.

An important economic advantage of the churn-immersion method is that it permits the use of a much smaller refrigeration unit than would be required in the surface cooler method using a direct expansion unit in which there is no reserve of refrigeration. With a ratio of at least 5 : 1 for water to milk, it will be sufficient to have the water at a temperature of 35° F. when the churns of milk are placed in the tank. It would not be necessary to have thermostatic control for the small farmer, as it will be quite sufficient for him to switch on the plant a few hours before the milk will be ready to go in the tank. In this way a small unit can be used to build up a store of refrigeration in the water. For the purposes of calculation of the amount of refrigeration required, we may assume that an ordinary 10 gal. churn will weigh about 35 lb., and that the iron will have a specific heat of 0·1. The 10 gal. of milk will weigh about 103 lb. and have a specific heat of 0·93. The efficiency of in-churn cooling is naturally increased if chilled water is used, and it is still further increased if the water flows over the outside of the churn. A modern equipment which employs this method is shown in Fig. Ci. 1.

In some types a coil is inserted into the milk, but there is always a possibility of contaminating the milk with this method.

It would obviously effect an economy in refrigeration if the churns could first be cooled down from 90 F.—which is the approximate starting temperature of the milk after the churn has been filled—to, say, about 65° or 70° F., by the use of unrefrigerated water. This method, however, would involve a complication, as either this water would have to be poured away and replaced by refrigerated water or else the churns would have to be transferred from one tank to another. It would probably be simpler and cheaper in the long run to have one tank of refrigerated water and to use this for cooling the milk down from its initial temperature.

A further important advantage of the churn immersion method is that it cools the churn as well as the milk and keeps the milk cool over-night. Hot nights are one of the commonest causes of the souring of milk; often, when the milk has been cooled efficiently over a surface cooler with a good supply of cold water (*e.g.* at 52° F.), by the time the milk has been run into the churn and the churn held over-night in a sultry atmosphere, the temperature has by the morning risen to 60° or 65° F., at which temperature bacterial growth is appreciable. On the other hand, with the churn immersion method, milk will fall to, say, 40° F. within 3 hr. of production, and what is much more important, will be maintained at a temperature of 35° to 40° F. throughout the night.

Disadvantages. There are inevitably certain disadvantages attached to the churn immersion method. One of the most frequent objections is to the trouble and difficulty involved in lifting the churns, but with proper planning of the method of handling milk and the position of the trough or tank, there should be little difficulty in this respect. Facilities should be provided to enable the churn to be rolled up to the edge of the water and then lowered gently into the water. A 10 gal. churn is about 24 in. in height and the level of the water should be about 18 in. In this way it will be found that the buoyancy of the full churn in the water is such that it is a comparatively easy matter for an ordinary person to lift out the churn on to the edge of the trough, from whence it may be rolled on to the waiting lorry.

Another objection that is frequently raised is that churn immersion gives only a slow cooling of the milk. It has been shown that it takes at least an hour for a churn of milk to be cooled to within a few degrees of the temperature of the water, and we should allow 3 hr. for the milk to come down to what is virtually the temperature of the water. Although it is naturally desirable that milk should be cooled immediately after production, this is not a serious objection as it is well established that bacteria do not grow in freshly produced milk for a few hours after the milk leaves the udder. There is no doubt, therefore, that compared with the great advantage the method has in avoiding contamination, this slight disadvantage is almost negligible.

One serious matter which has been raised by some buyers is that the immersion of churns in water leads to much more rapid corrosion. This will obviously be true if the conditions of the water are such that corrosion is possible. In practice the biggest factor is the *p*H or acidity of the water. If the locality is one in which the water is soft, corrosion will take place at a much greater rate and it will therefore be necessary to add a small amount of alkali to the water. If the water is chlorinated the chlorine will itself be a powerful catalyst in this corrosion and it is important therefore not to over-chlorinate the water, especially if the water is not alkaline.

Another objection that has been raised by some milk buyers is that when milk is cooled by the churn-immersion method the cream forms a greasy line inside the churn which is not removed by the ordinary churn-washing treatment. This has been denied by other buyers, and it is obviously a point which depends upon the mechanical efficiency of the churn washer.

It is naturally important in the churn-immersion method to ensure that no water gains access to the milk. Provided that a well-fitting lid is properly inserted and that churns which are not filled are placed in a special compartment where they cannot overturn, there would seem to be no danger in getting watered milk by the use of this method.

Finally, there is the objection that the cooling of milk by immersion of the churn will delay collection. This, of course, only applies to morning milk. Certain farmers are under the disadvantage of being at the start of the lorry driver's run and consequently often find the lorry driver waiting for them before they have all their milk ready for collection. It is argued, therefore, that in such cases churn immersion would be an impracticable method. There is no reason, however, why there should not be an arrangement for holding the empty churns clamped in the cooling trough and for the milk to be added to the churn from each cow as it is milked. In this way the cooling would be a gradual process and considerable cooling would have taken place by the time the last milk is added. It may be pointed out in addition that cooling is far more important for the evening milk than for the morning, because the evening milk is often 20 hr. old by the time it reaches the creamery and has to undergo platform rejection tests, whereas morning milk is taken in when only a few hours old. *See* Clean milk production ; Refrigeration.

Refs.: Scott (1953), *JDR*, **20**, 280; Scott (1953), *DI*, **18**, 772; Higginbottom (1952), *DI*, **17**, 327; Davis (1951), *SAB*, **14**, 216; Davis (1952), *F*, **21**, 467; Higginbottom (1951), *DI*, **16**, 241 (can immersion); Thiel, (1948) *JSDT*, **1**, 199, Stonebanks, *ibid.*, 202; Taylor, *ibid.*, 212; Milligan, *ibid.*, 219.

COPPER IN DAIRY PRODUCTS.

Ref.: McDowell (1947), *JDR*, **15**, 70 (estimation).

COPPER. Copper untensils and containers should be avoided as milk can dissolve traces of the metal after corrosion and such traces can catalyse oxidation of the fat to produce unpleasant taints, particularly *oiliness* (p. 475), in cold weather. Because of its high thermal conductivity, coolers are sometimes made of tinned copper, and the worn coolers can then be responsible for this fault. *See* Auto-oxidation ; Flavours; Metals.

Ref.: Bernhart and Linden (1950), *JDS*, **33**, 166.

CORK. The tissue of the bark of woody plants, mostly from phellogen or outer cortex. It is the common insulating material used in the dairy industry for brine tanks, storage tanks, rail and road tankers, cold stores, etc. Normally a 2-in. layer is used for road and rail tankers and a 4-in. layer for cold stores.

CORRELATION. The degree of relationship between two variables, *e.g.* two bacteriological grading tests, or the atmospheric temperature and the percentage of milk rejected at a creamery. *See* Statistical formulae.

CORROSION. This is usually defined as the destruction of metals by chemical and especially electro-chemical agencies. The mechanical destruction as by friction, rubbing, abrasion, etc., is termed *erosion.*

The most common type is oxidation of the metal to oxides or hydroxides. Salts may also be formed, *e.g.* carbonates and acetates in the presence of carbon dioxide, sulphide with hydrogen sulphide, sulphate by oxidation of sulphides, chlorides in the presence of brine, etc. If the new substance fails to form a firm adhering film the corrosion proceeds steadily, *e.g.* as with iron rust, but if a firm film is formed the corrosion is *stifled*, *e.g.* as with lead in sulphuric acid or silver in hydrochloric acid. *See* Brine; Churns, cleaning and sterilising; Cleaning and sterilising; Detergents; Metals; and various metals.

Refs.: Evans; Champion (1952), *Corrosion testing procedures;* Botham and Dummett (1949), *JDR*, **16**, 23.

CORYNEBACTERIUM. A genus of pleomorphic, non-spore-forming rods showing marked granulation, etc. It includes *C. pyogenes* the causative organism of "summer mastitis" (p. 660) and *C. diphtheriae* the common diphtheria organism. *See* Classification.

Refs.: Bergey; Wilson and Miles; Abd-el-Malek and Gibson (1952), *JDR*, **19**, 153.

COSTINGS, I. MILK PRODUCTION. The National Investigation into the Economics of Milk Production, inaugurated in 1934 and undertaken by the University Departments of Agricultural Economics in co-operation with the Ministry of Agriculture and the Milk Marketing Board, provides the most authoritative information on the costs of producing milk in England and Wales.

The latest information available is for the year ended 30 September, 1950, which, it should be noted, was a particularly favourable one for milk production, having as it did a mild and wet winter followed by a summer with above average rainfall. The average costs of production during that year for 660 herds in England and Wales are given in Table Cos I.

Average figures of costs must, of course, be studied with caution if wrong conclusions are to be avoided. The variation of costs from farm to farm is considerable; the actual range in the cost per gal. being from 13·0d. to 47·0d. Nevertheless, in spite of this wide range in costs from farm to farm, the significant fact is that the *relative* importance of the main items of cost is much the same on every farm. On all farms food and labour account for the bulk of production costs. Table Cos I shows that these items together accounted for approximately 80 per cent. of the gross costs on the farms under review. It is fairly obvious then, that it is the degree of efficiency with which labour and feeding are managed that will largely determine the profitability of milk production.

Food. Food costs in Table Cos I have been grouped under three main headings, "Purchased", "Homegrown" and "Grazing". Purchased foods have been entered at their cost to the farmer. The main homegrown foods have been charged at average costs of production on the farm, though the feeding value basis has been used for the less important fodder crops such as beet tops. The cost of grazing has been calculated for each individual farm.

Now that the full impact of the removal of the government subsidy on animal feeding-stuffs is being felt, many farmers are seeking ways and means of reducing their purchased food requirement. This substitution of homegrown for purchased food is more easily done on the large and medium-sized farms. On the small farm, however, the relatively higher turnover necessary in order to

COSTINGS : MILK PRODUCTION

TABLE Cos I

AVERAGE COSTS OF MILK PRODUCTION FOR 660 HERDS
FOR YEAR ENDED 30TH SEPTEMBER, 1950.

	Cost per cow			*Cost per gal.*	
	£	s.	d.	d.	%
Foods :					
Purchased . . .	19	6	0	6·4	27·2
Homegrown . . .	15	14	0	5·2	22·2
Grazing . . .	5	7	0	1·8	7·6
Total . . .	40	7	0	13·4	57·0
Labour	16	7	0	5·5	23·1
Miscellaneous . . .	10	9	0	3·5	14·8
Herd replacement . .	3	13	0	1·2	5·1
Gross farm costs . . .	70	16	0	23·6	100·0
Less credits for calves and manurial residues . .	3	13	0	1·2	
Net farm costs . . .	67	3	0	22·4	
Return . .	101	1	0	33·7	
Margin . .	33	18	0	11·3	

Average size of herd . . . . 28 cows
Average yield per cow . . . . 720 gal. per annum.

make a reasonable living can only be achieved in most cases by the intake of a large proportion of purchased food.

For economical feeding, cows should be fed according to yield. This, of course, necessitates the recording of the yield of milk of each cow at not greater than weekly intervals. A high food cost per cow is economically sound only when accompanied by a proportionately high milk yield per cow. A high food cost per gal. is almost always an indication of uneconomic production. High food costs are not always the result of excessive feeding: in some cases they are due to the high costs of production of the homegrown fodder crops.

Table Cos II shows differences in profit margin per cow at different rates of food consumption. For this purpose, herds are divided into groups at different levels of yield per cow, since obviously the food consumption per cow becomes higher as the yield increases. Not all the difference in the margins must be attributed to food alone. Other factors such as labour -which is shown in the table—grade of milk produced, seasonal production, etc., will also influence the figures. But rate of feeding is undoubtedly the main factor responsible for the difference in margins shown in Table Cos II.

Two important points are clearly illustrated in Table Cos II : (1) the margin per cow shows a marked upward trend as the average yield per cow increases, from £22·5 per cow for the herds averaging less than 600 gal. per cow to £49·2 per cow for herds averaging over 900 gal. per cow; (2) the trend within each yield group is for the margin to diminish as the level of food consumption increases. It appears, therefore, that some herds are being overfed in relation to the milk yield.

As grass provides a high proportion of the food requirement during the summer period, it is clear from the figure of £5 7s. per cow for grazing that grass is the cheapest form of food for the dairy cow.

TABLE Cos II

RELATIONSHIP BETWEEN MILK YIELD, CONCENTRATES FED AND PROFITABILITY * PER COW.

Weight of concentrates fed per cow	*No. of herds*	*Average size of herd*	*Concentrates*			*Total food*	*Labour*	*Total net cost*	*Total return*	*Margin*
			Bought £	*Home-grown* £	*Total* £	£	£	£	£	£
Cwts.			*Yield group under* 600 *gal. per cow*							
Under 15	4	44·6	11·0	1·0	12·0	30·7	11·5	50·1	77·6	27·5
15–25	3	15·9	16·5	8·9	25·5	41·5	19·0	80·5	84·1	3·6
25–35	—	—	—	—	—	—	—	—	—	—
Over 35	—	—	—	—	—	—	—	—	—	—
Yield group average	7	32·3	12·2	2·6	14·8	33·0	13·1	56·5	79·0	22·5
			Yield group 600–700 *gal. per cow*							
Under 15	5	54·5	9·8	3·7	13·5	28·2	13·5	56·1	95·3	39·2
15–25	10	26·0	16·0	6·1	22·1	39·4	17·5	72·1	98·8	26·7
25–35	4	38·6	25·7	4·2	30·0	44·7	18·4	78·0	94·1	16·1
Over 35	—	—	—	—	—	—	—	—	—	—
Yield group average	19	36·2	15·4	4·7	20·1	36·2	16·1	67·1	96·4	29·3
			Yield group 700–800 *gal. per cow*							
Under 15	2	20·1	8·6	1·8	10·4	23·1	21·5	50·5	92·9	42·4
15–25	6	35·3	15·5	4·0	19·6	37·8	17·6	68·9	104·8	35·9
25–35	3	50·9	19·6	8·9	28·5	45·6	17·4	78·1	106·5	28·4
Over 35	3	42·5	23·2	13·0	36·2	48·3	16·7	81·9	110·9	29·0
Yield group average	14	38·0	18·0	7·4	25·4	41·4	17·6	73·3	105·9	32·6
			Yield group 800–900 *gal. per cow*							
Under 15	—	—	—	—	—	—	—	—	—	—
15–25	3	19·5	23·9	1·4	25·4	46·4	17·5	80·8	121·5	40·7
25–35	7	32·1	22·9	5·9	28·8	45·2	17·2	77·3	118·2	40·9
Over 35	3	24·5	19·6	17·6	37·2	54·9	19·5	94·2	124·1	29·9
Yield group average	13	27·4	22·4	7·6	30·0	47·4	17·8	81·4	120·0	38·6
			Yield group over 900 *gal. per cow*							
Under 15	—	—	—	—	—	—	—	—	—	—
15–25	1	17·2	25·5	..	25·5	39·5	20·1	72·2	136·8	64·6
25–35	1	35·4	27·1	8·6	35·7	53·7	21·5	85·6	146·5	60·9
Over 35	5	22·9	33·9	7·8	41·7	62·4	23·1	106·3	149·6	43·3
Yield group average	7	23·8	31·6	7·2	38·8	58·2	22·4	98·4	147·6	49·2

* " Costs and Returns from Milk Production in the Southern Province in 1949–50." By R. S. Cook, Miscellaneous Cost Study No. 19, Department of Agricultural Economics, University of Reading.

TABLE Cos III

COMPARISON OF LABOUR COSTS ON MILK PRODUCTION BY SIZE OF HERD, MACHINE AND HAND MILKING FOR 660 HERDS FOR YEAR ENDED 30TH SEPTEMBER, 1950

Size of herd	5·0–9·9		10·0–19·9		20·0–29·9		30·0–39·9		40·0–49·9		50·0–59·9		60·0–134·5		*Total*	
	M.M.	*Hand*	*M.M.*	*Hand*	*M.M.*	*Hand*	*M.M*	*Hand*	*M.M.*	*Hand*	*M.M*	*Hand*	*M.M*	*Hand*	*M.M.*	*Hand*
Number of herds .	21	64	118	64	127	25	92	6	65	3	39	2	33	1	495	165
Average number of cows per herd .	8·2	7·5	15·8	13·9	24·6	22·8	35·1	33·5	43·9	41·6	54·1	54·8	81·0	94·8	32·4	14·9
Average yield, gals. per cow . .	693	704	721	672	695	743	714	852	725	731	767	703	719	658	721	713
Labour hours per cow . . .	183	227	155	202	147	190	142	234	138	187	132	196	119	117	139	202
Gal. per labour hour	3·8	3·1	4·7	3·3	4·7	3·9	5·0	3·6	5·3	3·9	5·8	3·6	6·1	5·6	5·2	3·5
	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.
Total labour cost per cow . .	20 0	24 6	16 10	21 9	16 2	20 18	15 15	26 11	15 18	21 3	14 8	24 19	13 12	15 2	15 9	22 4

Labour. In arriving at the labour cost, unpaid family labour is charged at rates equivalent to those received by corresponding classes of paid workers. Only direct dairy labour is charged to milk production, *e.g.* milking, feeding, cleaning of equipment and cowsheds. Labour for fodder crop production, including haulage to feeding point, is included in the cost of homegrown food. The labour involved in the rearing of dairy stock is not charged directly to the cost of milk production, but is, of course, reflected in the value of heifers entering the herds.

The figure of £16 7s. per cow or 5·5d. per gal., is the equivalent of 147 labour hours per cow, or in other words, 4·9 gal. of milk were produced for every labour hour. Here again the dispersion about the average is very great indeed, the labour hours per cow ranging from 68 to 546 and the gallons produced per labour hour from 1·1 to 11·0 gal.

This great variation in labour cost from farm to farm is due to a number of factors, the most important of which are size of herd, hand or machine milking and type and layout of buildings. The general trend is for the labour hours per cow to diminish as the size of herd increases. This is understandable as certain basic operations, *e.g.* the cleansing of a milk cooler, have to be undertaken irrespective of the number of cows.

Table Cos III shows the herds grouped according to size and sub-divided between machine and hand milked herds. This table clearly illustrates the reduction in labour per cow with increasing herd size. On average, hand milked herds expended 63 man hours, or £6 15s. per cow more than for herds milked by machine. Not all of this difference in labour requirement of the two groups should be attributed to the presence or absence of a milking machine; other factors mentioned previously will, of course, have had some influence, but it is obvious that the machine has had a pronounced effect on the figures.

With the general increase in wages, more and more farmers are turning to machine milking as a means of reducing the labour requirement. When, however, comparing the labour input for hand and machine milked herds, an important point to bear in mind is that it is not the total time that might be saved per annum by machine milking, but the time saved per milking. This is the crucial factor to consider on contemplating any reorganisation, which may take the form of reduction of dairy staff or their employment on other work in the time saved; or even an increase in the size of herd if conditions permit.

For all but the very small herds the saving in labour should more than offset the cost of running the milking machine. Other important considerations, however, such as the reduction in fatigue and the making of the task more attractive to the progressive type of worker, may, in themselves, justify the installation of a milking machine.

Miscellaneous expenses. Miscellaneous expenses as Table Cos I shows, account for approximately 15 per cent. of the gross costs of milk production. The items covered by this heading include rent of cowsheds and dairy buildings, bull upkeep and artificial insemination fees, milking machine expenses, equipment repairs and depreciation, fuel for sterilising, cleansing materials and disinfectant, veterinary charges, milk recording fees, share of general farm overheads, etc.

Many of these items are what might be called static costs offering little scope for control, and are not, of course, influenced to any appreciable extent by the volume of milk produced.

Herd Replacement. There are technical difficulties which prevent one from making a really satisfactory measurement of the cost of herd replacement in relation to the cost of milk production. For instance one must " eliminate " pedigree values of animals. The method used at present is to value pedigree animals at the same rate as non-pedigree cows of equal performance. The figures can therefore do no more than give an estimate of the charge.

COSTINGS : MILK PRODUCTION

Table Cos I shows the herd replacement figure to be £3 13s. per cow, or 1·2d. per gal., and accounts for approximately 5 per cent. of the gross cost. The annual replacement is in the region of 25 per cent. of the total number of cows per herd. From this, one must not assume that the average productive life of the dairy cow is only 4 years, as of course, many of the animals leaving the herds will continue their milking life on other farms.

Although the scope for reduction in the absolute cost of herd replacement is not large, strict attention to breeding and the prevention and eradication of disease and better breeding based on milk records will tend to keep this item to a minimum, and at the same time be reflected in higher yields thereby increasing the overall return from the enterprise.

Costs of Production for T.T. and Non-T.T. Herds. Table Cos IV shows costs and returns for the two grades of milk. Here again the average figures conceal a wide range in costs. Nevertheless the close similarity in cost between the two groups is interesting. One must, of course, take into account that size of herd and average yield per cow have been partly responsible for this similarity.

TABLE Cos IV

COMPARISON OF COSTS AND RETURNS FOR T.T. AND NON-T.T. MILK PRODUCTION
1949 50

	T.T.	*Non-T.T.*
Number of herds . .	385	275
Average no. of cows per herd	31 5	23 2
Labour hours per cow . .	147	147
Gallons per labour hour .	5.0	4 6
Seasonality: winter gal. as % of year . . .	49 6	49 4
Average yield, gal. per cow	743	675

	Per cow £ s.	*Per gal.* d.	%	*Per cow* £ s.	*Per gal.* d.	%
Foods:						
Purchased . . .	19 13	6 3	27	18 12	6 6	27
Homegrown . .	16 6	5 3	22	14 12	5 2	22
Grazing . . .	5 9	1 8	8	5 4	1 8	8
Total . .	41 8	13 4	57	38 8	13 6	57
Labour	16 11	5 3	23	15 19	5 7	24
Miscellaneous . . .	11 8	3 7	16	8 13	3 1	13
Herd replacement . .	3 6	1 0	4	4 5	1 5	6
Gross farm costs .	72 13	23 4	100	67 5	23 9	100
Less credits for calves and manurial residues .	3 16	1 2	-	3 8	1 2	—
Net farm costs . .	68 17	22 2	—	63 17	22 7	—
Returns	107 5	34 6	-	89 6	31 8	—
Margins	38 8	12 4	—	25 9	9 1	—

Only two items are likely to be increased as a result of T.T. milk production namely, labour and miscellaneous costs. There is, of course, the possibility that herd replacement costs might increase if an unusually high number of reactors had to be disposed of annually. Actually, as is shown in the table, the herd replacement figure is on average—once a T.T. herd is established—lower for the T.T. herds, partly due to the loss from other diseases being less for this group of farms.

It is generally agreed that the farmer producing T.T. milk has to spend more time on such tasks as sterilising of equipment, and in general maintains a higher standard of cleanliness of buildings and equipment than the farmer producing non-graded milk. The fact that Table Cos IV shows labour hours per cow to be identical for the two groups is no doubt partly due to the larger average size of herd of the T.T. group.

Miscellaneous expenses show the greatest difference between T.T. and non-T.T. herds; depreciation on boilers and fuel for sterilising accounting for most of this increase. Interest on capital for structural alterations to cowsheds and dairies to conform to the regulations concerning the production of T.T. milk is charged under the miscellaneous section.

The case for T.T. milk production is clear. Whilst it is recognised that there is a relatively small increase in costs, the overall margin per cow is greater. It is this higher margin per cow that determines profitability and the level of income.

Those persons who are interested in the costs of milk production in particular regions of the country are referred to the annual reports prepared by the Provincial Agricultural Economists at the Agricultural Departments of the following academic centres:

University College of Wales, Aberystwyth.
Departments of Economics, The University, Bristol 8.
School of Agriculture, Cambridge.
King's College, Newcastle-on-Tyne 1.
The University, Leeds 2.
The University, Manchester 13.
The University of Nottingham, Sutton Bonington, Loughborough.
The University, Reading.
Wye College, Ashford, Kent.

Costing Technique. The methods described are those at present being used in the National Investigation into the Economics of Milk Production.

Purchased food. A record of the various types of purchased food is kept and the amounts fed to the dairy herd are recorded. The food fed to heifers just prior to calving is included in the allocation to the dairy herd, as this " steaming up " period is intended to stimulate milk production.

Homegrown food. The amounts of the various homegrown foods fed to the dairy herd are recorded. This becomes a problem in the case of " loose hay ", root and green fodder crops. An occasional check can be made of the weight of a load. In the cases where crops are folded, the cost is apportioned on an acreage basis.

The cost structure of the fodder crops—with the exception of grass—is as follows:

Rent.
Cultivations (cost of manual, horse and tractor labour).
Manures (less residual values carried forward to subsequent crops).
Residual values of manures applied to previous crops.
Seeds and seed dressing.
Share of implement repairs and depreciation.
Share of hedging, fencing and ditching.
Share of general farm overheads.
Miscellaneous items (cost of binder twine, baling wire, thatching straw, rick pegs, etc.).

The costing of the grazing area will be as for the fodder crops shown above, but costs of establishing leys are apportioned over the expected life. In addition, a proportion of the cost of an area cut for hay or silage is charged for lattermath grazing. This proportion is varied according to the season and would be from, say, one-third to one-quarter of the cost of rent, cultivations and manures applied to the area—the harvesting cost of the hay or silage being a direct charge to that particular crop.

The apportionment of the total grazing cost to the various classes of livestock is carried out by the usual method of " cow equivalents ". That is to say, an adult cow is regarded as a unit and other classes of livestock are valued proportionately, having regard to their respective capacities for grazing. Allowances are made in the distribution of grazing costs between the summer and winter periods on the basis of season, location and any special local conditions.

Labour. A weekly record of the hours spent on milk production is kept for each individual worker and the appropriate charge made. The labour involved in the carting of fodder crops is not included under this section, as it is taken into account in arriving at the cost of production of the homegrown foods. Labour for the rearing of dairy stock is not a direct charge to the costs of milk production.

Herd replacement. The following example illustrates the method of arriving at the cost of herd replacement :

Valuation at beginning of year, 40 cows at £50	£2000	Valuation at end of year, 40 cows at £50	£2000
Home bred heifers transferred in, 8 at £60	480	Sales, 6 cows	200
		Deaths, 2 cows (value of carcases).	2
		Herd replacement . . .	278
48	£2480	48	£2480

It will be seen that the average value per head has been kept at the same figure at both beginning and end of year. This is done in all cases unless there is an increase in the quality of the herd during the year by the introduction of better class animals. At the present time the intake value of the home bred heifers is entered at estimated market value. It is intended that home bred heifers will be charged at actual cost to the farmer as soon as it becomes possible to undertake the necessary costings. As far as is possible, pedigree values are disregarded in arriving at the cost of milk production.

Miscellaneous charges. (*a*) *Rent of buildings.* A charge is made against milk production for the use of cowsheds and dairy buildings, the balance of rent being spread on an acreage basis—adjustments being made for rough grazings, woods, etc.

(*b*) *Equipment depreciation and repairs.* The broad principle is that the figure charged for depreciation should reflect as closely as possible the known conditions of physical deterioration and the likely degree of obsolescence. Only a proportion of the depreciation and repairs on equipment used jointly by the dairy herd and other livestock enterprises is charged.

(*c*) *Share of general farm overheads.* The section covers all the costs which cannot be directly charged to any one particular enterprise, *e.g.* accountant's and valuer's fees, postage and telephone, travelling and market expenses, non-productive labour, etc. The method used for apportioning these costs over the various enterprises is on a labour utilisation basis. That is to say the charge is made in the proportion of labour cost on the dairy enterprise to total labour cost (excluding non-productive labour) on the farm.

(*d*) *Milking machine expenses.* The charges under this heading include depreciation, repairs and replacements, and fuel for driving the machine.

(*e*) *Bull upkeep, service fees and artificial insemination.* The cost of maintaining the bulls, *i.e.* food, labour and replacement cost, together with costs for artificial insemination and service fees are charged.

(*f*) *Veterinary charges, milk recording fees, milk licences and consumable dairy stores.* The above are all charged at cost.

Credits. Calves are regarded as a by-product of milk production. Those sold within one week of birth are credited to the herd at their market value. Calves from pedigree cows and all others not sold within one week of birth are credited at commercial values.

Manurial residues of foods consumed by the dairy herd are calculated at the rates recommended in the report of the Scott-Watson Committee.*

See Agriculture; Dairy farm buildings; Diseases, animal; Feeding, Management of dairy cattle.

Ref.: Nalson and Jones (1952), *D*, **69**, 467.

COSTINGS, II. PROCESSING AND DISTRIBUTION. Raw milk is purchased at a price which normally includes the cost of delivery to the buyer's premises, but before this milk is finally delivered to the consumer, additional expenses are incurred in the form of processing and delivery costs. These subsequent costs are matters of vital interest to the dairy manager, not only because of their direct influence on the net profit to be made, but because they also provide an accurate indication of the degree of efficiency of the management and organisation of the dairy. In order to ensure effective control, therefore, it is essential that the manager should be fully conversant with the detailed and up-to-the-minute costs incurred as a result of the various operations carried out under his supervision.

For accountancy purposes, every business organisation segregates its trading activities into financial periods—either annual or half-yearly—at the end of which time the firm's accountant prepares a financial report which includes the compilation of a Profit and Loss Account. From this report it is possible to extract information as to expenses incurred relative to the various operations carried out, from which costings figures may be prepared, but these are of little value from a management viewpoint since they are only available, at most, every six months. Moreover, in general, such costings are not sufficiently detailed to serve the purpose for which they are required.

What the dairy manager requires is a knowledge of the *weekly* costings relative to the various operations being carried out under his control, so that any tendency for costs to increase in any particular section of the business may be noted, the reason for such increase determined, and the fault, if any, rectified. In this manner the organisation of the business may be maintained at the highest pitch of efficiency.

Consideration of the question of costings will show that expenses fall into two main classes which may be termed static and variable. Static expenses are those which do not vary from week to week, and in the compilation of weekly costings figures are best dealt with by reducing to a proportionate weekly charge. Variable expenses include such charges as wages, trade requisites, wastage, etc., which fluctuate to a greater or less extent, and such expenses are costed on the actual weekly figures. It is therefore essential to keep accurate records of such items, showing, for example, the actual usage of trade requisites, wastage of milk and so on. These details may conveniently be recorded as shown in Tables Cs I to V. For the purpose of convenient comparison, all expenses should be reduced to a cost-per-gal. basis, and for this calculation the gallonage used should be the raw milk received and not the milk sold. The reason for this is, that the costs which are to be determined are those which must be added to the purchase price of the raw milk before it reaches the hands of the consumer.

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* Agriculture: *The Journal of the Ministry of Agriculture*, July, 1946, Vol. liii, no. 4, pp. 163-170.

A. *Processing Costs.* (1) ***Static expenses.*** (*a*) ***Rent, rates and insurance.*** As already mentioned, these items do not vary from week to week, so that, in compiling weekly costings figures the annual sum involved should be divided by 52 in order to allocate the appropriate weekly charge. This latter charge should then be divided by the gallonage intake figure to obtain the cost per gal.

TABLE Cs I

STOCK CONTROL STATEMENT

Week ending

Item	*Stock to begin*	*Received during week*	*Stock to end*	*Used during week*	*Price*	*Cost*			*Cost per gal. (pence)*
						£	s.	d.	
					(*a*)				
					(*a*)				
					(*a*				
					(*a*				
					(*a*				

TABLE Cs II

MILK WASTAGE COSTS

Week ending	*Intake gal.*	*Wastage*		*Cost*			*Cost per gal. (pence)*
		gal.	%	£	s.	d.	

TABLE Cs III

TRANSPORT COSTS

Week ending	*No. of hr.*	*Rate per hr.*	*Cost*			*Intake gal.*	*Cost per gal (pence)*
			£	s.	d.		

TABLE Cs IV

WAGES COSTS

Week ending	*Intake gal.*	*At basic rate*	*Cost per gal. (pence)*	*At overtime rate*	*Cost per gal. (pence)*	*Gross wages*	*Cost per gal. (pence)*
		£ s. d.		£ s. d.		£ s. d.	

TABLE Cs V

MILK BALANCE STATEMENT

Week ending

Receipts	*gal*	*Disposals*	*gal.*
Stock to begin . . .		Sales	
Raw milk received . . .		Manufactured	
		Stock to end	
		Wastage	
Total		Total	

Wastage = % of milk received

It will be appreciated that the cost per gal. figure will vary slightly according to sales fluctuations, which cause corresponding intake fluctuations, becoming lower as trade increases and vice versa.

(*b*) *Depreciation and interest* (Plant and Buildings). The amount charged under this heading will depend entirely on the policy adopted by each individual firm. Dairy machinery, by virtue of the fact that it is continuously in use, that it endures abnormal metallic stresses and strains due to expansion and contraction under widely varying temperature conditions, and that it must be dismantled and reassembled daily during cleaning operations, has a comparatively short life. From the accountancy viewpoint, therefore, it is a wise policy to depreciate fairly heavily, and an annual rate of 16 per cent. on the purchase price is not unusual. It is true that many items of modern dairy plant can be used satisfactorily for a much longer period than 6 years but, frequently, the increased maintenance costs which are incurred after this period arouse doubt as to the economic soundness of such a policy. Moreover, almost inevitably, the production of new and improved machines which are capable of rendering an improved product or of operating more economically, has made the existing plant obsolete by the end of this period. It is, nevertheless, only fair to state that, given careful management and a properly-trained staff, the useful life of dairy plant may be prolonged for an appreciable period beyond 6 years.

For the purpose of weekly costings compilation, therefore, the annual depreciation and interest charges should be reduced to a weekly charge from which a cost-per-gal. figure may be calculated as previously described. Here again, the cost-per-gal. will vary slightly in accordance with trade fluctuations.

(*c*) *General overhead expenses.* These include such items as clerical wages, postage and telephones, cleaning, lighting and heating of office premises, printing and stationery, insurance, advertising, travelling expenses, directors' fees, and other items of expenditure relative to the upkeep of the establishment. In a large business concern, these expenses can conceivably amount to a very large sum and will appreciably influence the final cost-per-gal. figure. In certain multiple firms and co-operative societies where the trading activities cover several spheres, *e.g.* dairy, bakery, catering, grocery, etc., these " Head Office expenses " are allocated to each department proportionately, according to their respective annual cash sales. For weekly costings purposes it is usual to break down the total charge for the previous financial period to a weekly figure, which, in turn is divided by the gallonage intake to determine the cost per gal.

(*d*) *Administrative salaries.* This item of expenditure does not normally vary from week to week, and, since in many cases salaries are paid monthly to managers and supervisory grades of employees, it is convenient to average these on a weekly basis for costings purposes.

(*e*) *Repairs and maintenance.* This item covers the cost of engineering and other maintenance staff, repairs to plant, including the supply of new parts, and also repairs to buildings. It may be argued that these are variable expenses in that they will fluctuate from week to week. It is, of course, true that these expenses do vary, but it is precisely because they vary so widely that it is not desirable to charge them as a direct weekly cost. Dairy machinery may conceivably function for several weeks running with little or no attention in the way of maintenance, whereas occasions periodically arise when comparatively heavy costs are incurred for repairs and renewals. To charge these costs directly as and when they are incurred would therefore result in causing wide fluctuations in overall weekly costs which would give a somewhat distorted picture of the true situation. In general, the annual costs incurred relative to general maintenance and repairs do not vary widely from year to year, except that there is a tendency to a slight progressive increase as plant and equipment becomes more aged. For the purpose of computing weekly costings, therefore, it is sufficiently accurate to reduce the previous annual cost to a static weekly figure.

(*f*) *Laboratory requisites.* It is more convenient to include the cost of laboratory requisites as a static charge because of the difficulty of ascertaining the exact amount of reagents, etc., used each week. A well-equipped laboratory contains a very large variety of chemical and bacteriological reagents, the exact weekly usage of each of which would be both difficult and inconvenient to determine by means of weekly stocktaking. Moreover, the purchase of replacements and renewals of reagents, glassware and equipment normally takes place at irregular intervals so that—as is the case with plant maintenance and repairs—it is more suitable to reduce the cost of the previous annual purchases to a static weekly figure for weekly costings purposes.

All the static weekly charges should be reduced to a cost-per-gal. basis by dividing by the weekly gallonage intake. It will therefore be appreciated that, as trade fluctuates there will be a corresponding fluctuation in the cost-per-gal. figure of these charges, increasing trade resulting in a reduction of per-gal. costs.

(2) ***Variable expenses.*** The variable expenses include such items as wages (including National Health Insurance—Employer's Liability), cost of transport from processing dairy to distributive depot, trade requisites (*e.g.* bottles, discs,

aluminium, detergents, crates, etc.), wastage, fuel, power, lighting and water. These charges are of particular interest to the dairy manager because, unlike the static expenses, they are directly under his control, and provide, therefore, an indication of the efficiency of his administration. For weekly costings computations the variable expenses are charged at their actual amount and reduced to a cost-per-gal. figure by dividing by the weekly gallonage intake.

(*a*) *Wages.* Minimum rates of wages for *all* workers employed in the Milk Industry are defined by the Ministry of Labour and National Service, under the Wages Council Act, 1945, in various Wages Regulation Orders issued from time to time. These Orders specify the statutory minimum remuneration for all grades of workers—male and female—and also lay down regulations in relation to such matters as overtime rates, holidays with pay, and so forth. The minimum wages rates vary in accordance with locality, the country being sub-divided into three areas—A, B and C—in each of which a different scale of wages obtains. The highest rate is paid in Area C which comprises the City of London and the Metropolitan Police District, while Area A, comprising areas administered by Rural District Councils and those administered by Municipal Borough Councils or Urban District Councils having an estimated resident population not exceeding 10,000, enjoys the lowest rates. Area B, in which the minimum rates are intermediate between those applicable to Areas A and C, comprises all areas not included in those two areas. It should be noted that the wages rates specified by the Milk Distributive Wages Council are minimum rates, and that many firms pay rates which are appreciably in excess of these.

In general, wages costs constitute the greatest item of expenditure to be met with in the dairy and can only be kept to a minimum by efficient managerial organisation, adequate plant capacity, and effective dairy design. Successful management in this respect depends largely on making certain that each employee is allocated to the type of work to which he is best adapted, in providing suitable rest periods and welfare facilities, and in knowing—and exacting—the amount of work which may reasonably be expected from each individual. Increased wages costs will inevitably accrue as a result of inadequate plant capacity, because of the overtime payments—at higher rates—which will be necessitated, while bad dairy design and plant layout will necessitate the employment of additional and uneconomic labour. The increased use of such items of equipment as power-driven conveyors will frequently accomplish an appreciable reduction in wages costs.

(*b*) *Transport.* Next to wages, the cost of transporting milk from the processing dairy to the distributive depots is probably the highest item of expenditure experienced in milk handling, and although this service really constitutes the first phase of distribution, it is usual to include its cost as a charge against processing. Most large dairy firms and co-operative societies confine their transport work to a separate self-contained Traffic Department, in which case vehicles are charged at an hourly rate which includes all costs such as wages, fuel, maintenance, depreciation and overhead charges. Effective control of transport costs involves the careful organisation of loads and routes so that the greatest possible quantity of milk may be carried over the least possible mileage, and that all vehicles shall return a full load of empties to the processing depot rather than return unladen.

The cost of transport per gal. of milk carried is also influenced by the type of container in which the milk is packed and the weight of the crate in which the containers are packed. For example, a standard 15 lb. metal stacking crate filled with 20 × 17¼ oz. pint bottles containing milk has an overall weight of 62¼ lb. of which only 25¾ lb. (41·37 per cent.) consists of milk. This means that, for traffic purposes, 58·63 per cent. of the load is unprofitable. Similarly, a 15 lb. crate containing 12 × 27¾ oz. quart bottles filled with milk has an overall weight of 66¾ lb., of which 31 lb. (46·44 per cent.) constitutes the weight of milk, so that the unprofitable portion of the load in this case amounts to 53·56 per cent.

It will be clear, therefore, that—other things being equal—the use of larger sized bottles results in greater economy in transport expenses, computed on a cost-per-gal. basis, because of the higher ratio of milk to total weight. In this connection an appreciable saving in transport costs can be effected by the use of paper cartons as milk containers. In the case of one particular make of cartons, the total weight of 24 pint size cartons filled with milk and packed in a cardboard box is 34¼ lb. This is equivalent to a total weight per gal. of 11 lb. 7 oz., whereas the total weight per gal. in the case of a crate of full pint bottles as quoted above amounts to 24 lb. 15 oz. While, in theory, the use of cartons should permit the reduction of transport costs by 50 per cent., in practice it is found that the amount of milk which can be transported in cartons is limited by considerations of *bulk* rather than weight, and that, in fact, it is only possible to increase the quantity of milk transported in this type of container by 25 to 30 per cent. as compared with bottled milk.

(*c*) *Trade requisites.* Included under this heading are such items as fuel, churns, crates, bottles, discs, aluminium foil, straws, detergents, filter-cloths, cleaning materials, as well as all the minor articles of everyday use. For the purpose of compiling weekly costings figures it is essential to ascertain the actual usage of these materials during the week. This necessitates a weekly stocktaking and the compilation of a stock control statement of the type illustrated in Table Cs I. This enables the dairy manager not only to ascertain the cost of the materials used during the week, but also to exercise an effective control over stocks and to place orders for replenishments in good time. While churns and crates have been included in the above list, these items are not readily destructible and are commonly included as a static expense based on the cost of the previous year's renewals, reduced to a weekly charge.

The comparative ease with which the milk bottle may be broken or otherwise become lost to the dairyman, results in an expenditure on this item of equipment which has an appreciable influence on processing costs. The " life " of a milk bottle is normally reckoned in terms of the average number of journeys it makes, this figure being computed by dividing the number of bottles lost into the number issued from the processing depot. This figure varies widely due to a variety of circumstances, but probably averages about 50 journeys throughout the country as a whole—equivalent to a loss of 2 per cent. of all bottles issued. Processing costs, however, are influenced not only by the actual wastage of bottles, but by the proportion of the different sizes of bottles filled. This point is illustrated by the following figures :

Size of bottle	*Cost per gross*	*Cost per bottle*
Quart	61s.	5·083d.
Pint	40s.	3·333d.
Half pint	32s. 9d.	2·729d.
Third pint	27s.	2·250d.

Based on the assumption that the average life of the bottle is 50 journeys, the bottle cost per gal. would vary according to size as follows :

$$\text{Bottled in quarts} \quad \frac{5\cdot083 \times 4}{50} = 0\cdot406\text{d. per gal.}$$

$$\text{Bottled in pints} \quad \frac{3\cdot333 \times 8}{50} = 0\cdot533\text{d. per gal.}$$

$$\text{Bottled in half pints} \quad \frac{2\cdot729 \times 16}{50} = 0\cdot873\text{d. per gal.}$$

$$\text{Bottled in third pints} \quad \frac{2\cdot250 \times 24}{50} = 1\cdot080\text{d. per gal.}$$

These figures clearly demonstrate that the cost of bottles per gal. increases with the decreasing size of the bottles used, so that processing costs will vary in accordance with the proportions of the various sizes of bottles which are filled.

Further, the output of the plant in gal. per hr. is decreased, and the cost per gal. for power and labour is correspondingly increased by the use of smaller-sized bottles.

(*d*) *Wastage.* Milk wastage or process losses, if improperly controlled, may constitute a serious loss to the dairyman and appreciably influence processing costs. For costings computations it is advisable to compile a weekly Milk Balance Statement (Table Cs V) on which are recorded milk stocks, receipts and disposals, from which can be calculated the actual loss in processing. Wastage arises from a variety of causes including spillage, leakage from damaged milk pipe joints, evaporation losses during pasteurisation, and cooling (especially where open-surface heating and cooling is employed) and losses due to overfilling of bottles, this latter factor bearing by far the greatest responsibility in this respect. The manufacturers of milk bottles are not yet able to guarantee absolute accuracy in capacity, so that, for their own protection and that of their clients, all bottles are manufactured slightly oversize Moreover, in practice it is almost impossible to fill bottles—except by the use of machines fitted with measuring devices—to a constant level, since the amount of milk filled into the bottle is influenced by a number of factors such as the extent of displacement by the filling-valve, the head pressure of milk in the filler bowl and in the balance tank or processed milk storage tank, and the consistency of speed of the filling machine Frequent stoppages in the process of bottle filling also result in the overfilling of bottles, because the consequent extended period during which the bottles are held under the open filling-valve permits a little extra milk to flow into the bottle For these reasons increased wastage costs are frequently an indication of faulty filling machines, or lack of adequate supervision in the dairy. For costings computation the wastage expense should be calculated on the purchase price of the milk and not on its retail value.

(*e*) *Power, lighting, and water.* These items are, in general, all metered, and the weekly costs can be calculated from the meter readings The usage of power, lighting, and water on a cost-per-gal of milk basis will vary according to the efficiency of operation of the dairy, in as much as any factor which reduces the rate of output of the plant will increase the duration of the processing run with a consequent increase in the usage of these items

Having thus obtained all the various weekly charges denoted above and reduced them to a cost-per-gal basis by dividing by the weekly gallonage intake of milk, it is then possible to compile weekly costings statements of the type illustrated

TABLE Cs VI

PROCESSING COSTS

	Week ending			
	£	s	d	*Cost per gal (pence)*
Wages	1725	12	4	1 827
Administrative salaries	80	10	10	0 085
Overhead expenses (including depreciation and interest)	975	18	4	1 028
Repairs and maintenance	367	19	8	0 387
Laboratory requisites .	14	11	5	0 015
Fuel, power and water	692	5	1	0 730
Trade requisites	570	6	11	0 602
Bottle wastage	351	2	10	0 370
Transport	889	12	5	0 937
Milk wastage	276	4	10	0 291
	5944	4	8	6 272

Milk received = 227,458 gal

in Table Cs VI. These are of considerable value for management purposes for, by comparison from week to week, control may more readily be exercised and rising expenses checked.

B. ***Distribution Costs.*** Efficient and economic milk distribution is entirely dependent on the ability to distribute the largest possible quantity of milk by means of the least possible amount of labour and transport. This in turn is influenced by various factors, such as the extent and topography of the delivery round, the type of vehicle used, the concentration of trade in the area, whether or not other goods are sold by the roundsman, whether or not accounts are collected by the roundsman, and the physical condition of the roundsman himself. It is obvious that a roundsman operating in a flat, congested area will be able to deliver more milk per hr. than one whose round covers an area in which the terrain is hilly and the trade widely dispersed. It is equally clear that, in the latter case, more milk per hr. could be delivered by a horse-drawn or mechanically-propelled vehicle than by a hand-propelled barrow, with a consequent reduction in the wages cost per gal. The rate—and consequent cost—of milk delivery in any area is also influenced by the type of dwelling house, *e.g.* whether there is a preponderance of flats, or whether, in the case of non-flatted property, the houses abut on the roadway or are situated well back from it. The sale of goods other than milk by the roundsman increases the time required to cover his area and correspondingly reduces the rate of milk delivery, as does also the fact of his having to collect accounts. In this latter connection, considerable time may be saved by the use of a token system whereby customers may purchase tokens from shops or offices of the dairy firm concerned which they later surrender to the roundsman in return for milk. The roundsman is thus relieved of the delay and clerical work occasioned by the collection of accounts, while his employers obviate the risk of contracting bad debts. The physical ability of the roundsman is considerably influenced by the type of vehicle he uses. For example, a roundsman pushing say, 40 gal. of milk on a handbarrow—the bottled and crated milk weighing approximately 25 lb. per gal.—has to cope with a weight of 1000 lb. in respect of the milk alone, irrespective of the weight of the barrow ; so that, with this type of vehicle, the physical condition of the roundsman is a matter of very considerable importance in relation to delivery costs.

In computing weekly distribution costs there are—as with processing costs—both static and variable expenses to be considered. The static expenses include depreciation and interest on vehicles and buildings, maintenance and repairs to vehicles and buildings, rates and insurance, and general overhead expenses. It is also convenient to include under this heading horse expenses and power, since these charges do not vary greatly from week to week. Horse expenses includes all items appertaining to the feeding and management of the horses, *e.g.* fodder, stabling, stable labour, shoeing, harness repairs, etc., while power expenses are those incurred in the charging of electric vehicle batteries. This means, in effect, that the only variable expense is the wages cost. These various expenses may be dealt with in the manner described under " Processing Costs ", but it is more usual to relate all the static charges to vehicles under the heading of Distributive Vehicle Costs. In this connection it should be noted that depreciation will vary to some extent according to the type of vehicle. Handbarrows, horse-drawn vehicles and electrically-propelled vehicles which suffer comparatively little wear and tear of moving parts are normally depreciated over 10 years, while motor vehicles, which deteriorate more rapidly due to their more numerous moving parts and the constant starting and stopping inseparable from milk delivery, are depreciated over a period of 5 years.

Distributive vehicle costs. The total weekly vehicle charges are calculated under two headings :

(*a*) *Maintenance and depreciation of vehicles.* This includes all charges relevant to garaging, stabling, horse-feed, vehicle repairs, as well as depreciation and interest. These charges may be extracted from the Accountant's Financial Report and reduced to a basic weekly charge:

1. Hand barrows	£0 9s. 3d. per week.
2. Electric barrows	1 16s. 2d. ,,
3. Horse vans	4 13s. 11d. ,,
4. Electric vans (18-22 cwt.)	4 18s. 10d. ,,

(*b*) *Overhead expenses.* To these charges must now be added various static overhead expenses such as superannuation, insurance, depot maintenance and repairs, sundries and general overhead expenses. These are calculated on a cost-per-gal. basis from the previous year's annual expenses, and may conceivably be as under:

Superannuation (Employer's contribution)	0·0851d. per gal.
Insurance (Employer's liability)	0·0158d. per gal.
Depot maintenance and repairs	0 0467d. per gal.
Sundries	0·0058d. per gal.
General overhead expenses	0·4265d. per gal.
	0·5799d.

Each vehicle must bear its proportion of these charges, which are most fairly allocated on the basis of the average weekly gallonage sales of the particular type of vehicle:

Average weekly output (gal.)

1. Hand barrows . . 552 × 0·5799d. = £1 6 8
2. Electric barrows . . 738 × 0·5799d. = £1 15 8
3. Horse vans . . . 825 × 0·5799d. = £1 19 10
4. Electric vans . . 869 × 0·5799d. = £2 2 0

The total weekly vehicle charges are therefore as follows:

(*c*) *Total weekly vehicle charges*

Type	*Maintenance and depreciation*	*General overheads*	*Total*
land Barrows	£0 9 3	£1 6 8	£1 15 11
lectric barrows	£1 16 2	£1 15 8	£3 11 10
lorse vans	£4 13 11	£1 19 10	£6 13 9
lectric vans	£4 18 10	£2 2 0	£7 0 10

Calculated in this way, each vehicle bears its due proportion of the total distributive expenses excepting wages, commission and salaries; and, with the aid of suitable records it is possible to build up a weekly Distribution Costs Statement. Administrative and other Supervisory salaries may be broken down to a weekly figure which may conveniently be charged to the distributive depots on a cost-per-gal. basis in proportion to the weekly gallonage output of the depot.

Tables Cs VII to Cs XI inclusive illustrate the suggested method of building up a weekly distribution costs statement relative to two distributive depots—one, from which operate 2 electric barrows and 31 18 to 22 cwt. electric vans; and the other, from which operate 5 hand barrows and 8 horse vans.

For management purposes it is also important to know the Basic Economic Sales Level of a delivery round as operated by each type of vehicle, *i.e.* the gallonage sales figure at which the gross profit on sales accurately balances the total expenses of the round, including wages and total vehicle charges. The wages expenses charged against the round must, of course, include a proportionate

COSTINGS: PROCESSING AND DISTRIBUTION

TABLE Cs VII

Weekly Gross Wages Analysis

Week ending

Depot	Foremen	Roundsmen				Total
		Barrows	*Electric barrows*	*Horse vans*	*Electric vans*	
	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d
A	22 19 8	—	20 0 0	—	328 2 7	371 2 3
B	10 3 11	45 12 3		72 13 5		128 9 7
etc						

TABLE Cs VIII

Weekly Commission Costs

Week ending

Depot	*Barrows*	*Electric barrows*	*Horse vans*	*Electric vans*	*Total*	*Sales gals*	*Cost per gal*
	£ s d	£ s d	£ s d	£ s d	£ s d		
A		4 14 0		79 0 0	83 14 0	27,752	0·72
B	9 7 0	–	15 16 6		25 3 6	9,359	0·64
etc							

TABLE Cs IX

Weekly Sales Record

Week ending

Depot	*Barrows*	*Vehicles*				*Barrows gals*	*Electric Barrows gals*	*Horse vans gals*	*Electric vans gals*	*Total gal*
		Electric barrows	*Horse vans*	*Electric vans*	*Total*					
A		2	–	31	33		1605½		26,146½	27,752
B	5		8		13	3060		6299		9359
etc										

TABLE Cs X

Weekly Total Wages Costs

Week ending

Depot	*N H I*	*Inspectors' salaries (proportion)*	*Admin. salaries (proportion)*	*Direct wages*	*Total wages*
	£ s d	£ s d	£ s d	£ s d	£ s d
A	7 14 2	6 4 0	21 7 1	371 2 3	406 7 6
B	3 6 8	3 11 8	7 19 6	128 9 7	143 7 5
etc					

TABLE Cs XI

WEEKLY DISTRIBUTION COSTS

Week ending

Depot	*Total wages*	*Overhead charges*	*Total*	*Sales gals.*	*Cost per gal.*
	£ s. d.	£ s. d.	£ s. d.		*pence*
A	406 7 6	209 13 6	616 1 0	27,752	5·327
B	143 7 5	57 6 6	200 13 11	9,359	5·147
etc.					

charge for rotary roundsmen (1 in 6) who relieve regular roundsmen on rest days, and auxiliary roundsmen (1 in 10) who must be employed to cover sickness and holiday duties. Taking the figure already given for an 18 to 22 cwt. electric van and the processing costs at 5·315d. (Table Cs VI) the Basic Economic Sales Level may be computed as follows:

Basic Economic Sales Level—18 *to* 22 *cwt. electric van*

Total weekly vehicle costs		£ 7 0 10
Wages		
1 Roundsman	at £6 4 6	6 4 6
1 Boy	at 2 17 0	2 17 0
1/6 Rotary roundsman	at 6 4 6	1 0 9
1/6 Rotary boy	at 2 17 0	0 9 6
1/10 Auxiliary roundsman	6 5 0	0 12 6
N.H.I. (Employer's share)		0 6 4
		£18 11 5

NOTE. *Wages calculations are based on Milk Distributive Wages Council Regulation M.D. 72 dated* 17 *October* 1953, *and on the assumption that no overtime payments are incurred.*

	per gal.
Purchase price of milk	£0 2 11¼
Less Heat treatment and bottling allowance	0 0 1⅞
	£0 2 9⅜
Retail price of milk	0 4 0
Gross margin	£0 1 2⅝
Cost of processing and transport	0 0 6·272
Residual distribution margin	0 0 8·353
The Basic Economic Sales Level is therefore	$\frac{£18\ 11\ 5}{8\cdot353\text{d.}}$ gal.
	= 534 gal.

The significance of this is, therefore, that on a delivery round operated by an 18-22 cwt. electric van under the conditions specified above, 534 gal. of milk must be sold in order to balance the expenses of the round. By calculating the Economic Sales Level for rounds operated by the various types of vehicle under his control, the dairy manager is enabled to adjust unprofitable rounds accordingly, and thus reduce distributive costs and increase profits.

In many dairy firms it is customary to pay commission to roundsmen based on sales, in order to encourage salesmanship. Several systems of commission payments are in use, the most common being payment on a gallonage basis above a determined datum line. It should be appreciated that commission payments are essentially a charge against profits, and should therefore only be made out of profits. This being the case, it is obvious that, before such payments can be made, a sufficient quantity of milk must have been sold on the round that the gross profit on these sales covers the total expenses of the round. In other words, the datum line in any scheme for the payment of commission on sales must be the Basic Economic Sales Level of the round as operated by each individual type of vehicle. For the purpose of weekly costings computations, commission payments rank as a variable expense and are reduced to a cost-per-gal. figure each week in the usual way. *See* Management of creameries, of pasteurising depots ; Milk marketing; Retail; Transport.

Refs. : Chocholouschek (1947), *M*, **2**, 222 ; Charles (1949), *IDC*, **4**, 52 ; Walworth, 62 ; Joost, 117 ; Maider and Bagstam, 129 ; Erland (1949), *IDC*, **5**, 124 ; Emilsson, 131 ; Walworth (1953), *IDC*, **3**, 1509 ; Reid (1948), *D*, **65**, 194, 240 and 295 ; **66**, 21 ; Walworth ; Enock ; Williams.

COTTAGE CHEESE. A simple type of skim milk cheese.

COULOMB. The unit of electric quantity, 1 amp. flowing for 1 sec.

COULOMMIER. *See* Cheese, p. 189.

COUNTING BACTERIA. *See* Bacteriological grading of milk ; Microscopic count ; Plate count.

COW, INTERNAL ORGANS OF. *See* Fig. Cw 1. and Milk secretion.

COWS. *See* Breeding ; Feeding ; Management of cattle.

CRATES (for bottles). Stout open framework baskets, usually made of galvanised or tinned steel. The design and construction of crates is a subject worthy of some study. The following points should be considered : (*a*) durability ; (*b*) ease of loading ; (*c*) tendency to break bottles, not only in loading but also in stacking ; (*d*) ease of man-handling ; (*e*) ease of stacking ; (*f*) weight ; (*g*) ease of cleaning ; (*h*) resistance to corrosion.

Crates usually contain 30 third pints, 24 half-pints, 20 pints, or 12 quarts.

See Mechanical handling.

CREAM. Cream is a concentration of the fat globules in milk obtained by centrifuging ; and either sold as such or used for making butter, cream cheese, etc. The fat content of cream varies according to conditions and requirements. For buttermaking and most purposes a fat content of about 38 per cent. is most popular. Higher values lead to lumps and curdiness ; low values entail relatively greater transport charges for a given yield of butter.

The manufacture of cream was prohibited during the war but in 1951 sale was permitted for a few weeks. The standards laid down were : single cream 18 per cent. (usually homogenised), double cream 48 per cent., canned cream (p. 322) 23 per cent. Sale is now unrestricted.

Manufacture. If cream is to be sold raw, separation should be carried out at 85° F. to obtain the results described, but if the cream is to be pasteurised the temperature of separation does not matter.

Heat Treatment. Probably the best method is to heat to 180-190° F. for a short time, *e.g.* 10 sec., cold store at 40° F. for 24 hr., and then repeat the heating process. Heat penetration is only slightly slower than that for milk. Special plates for cream are made by some manufacturers of H.T.S.T. plants.

For the holding method a temperature of 145-155° F. for a period of 30-60 min. may be used. This is the standard method in U.S.A. An independent cooler will increase output for obvious reasons. Coil types of heating pans are difficult to clean and sterilise.

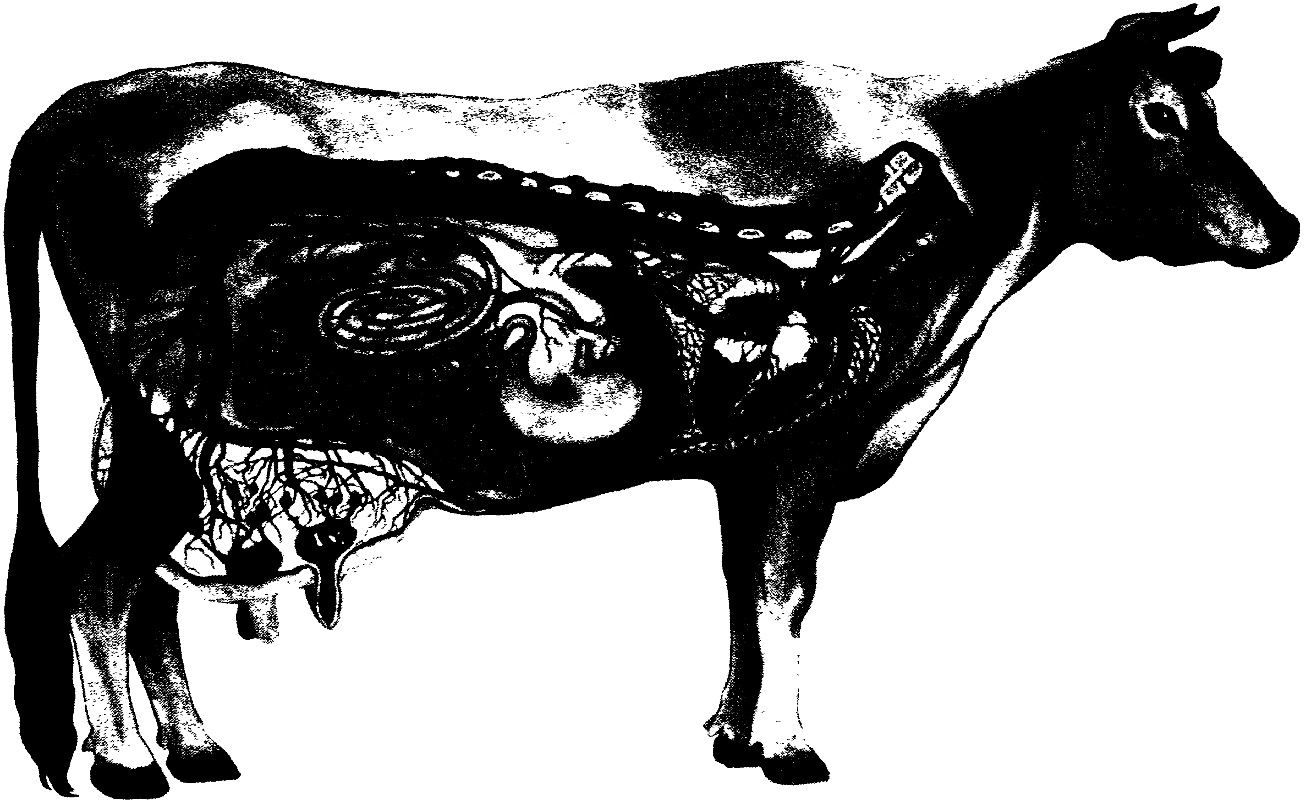
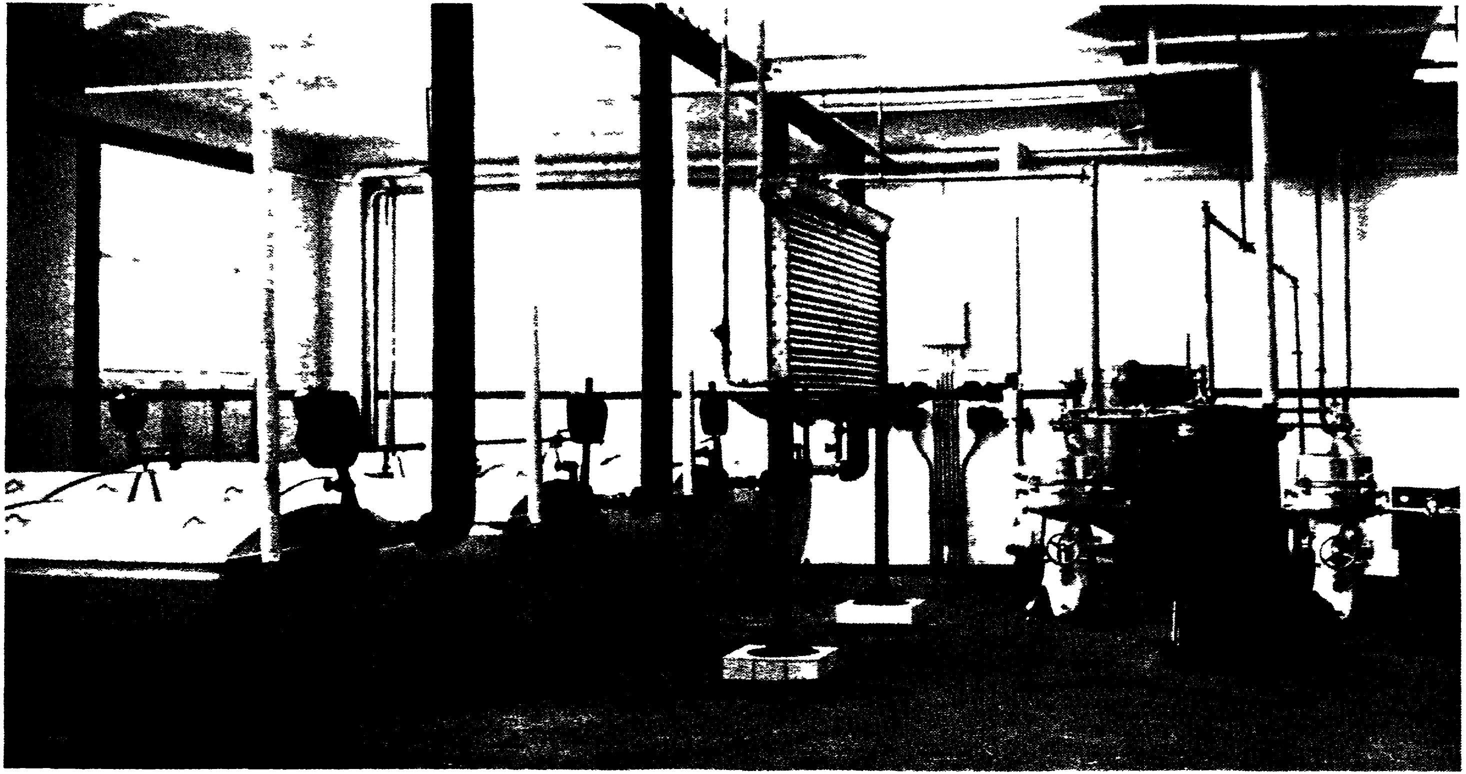


FIG. Cw 1.—*Digestive and Blood Systems of Dairy Cow.*



[*By courtesy of the Milk Marketing Board*

FIG. C1 1 —*Preheaters, Separators, Coolers, and Storage Vats for Cream*

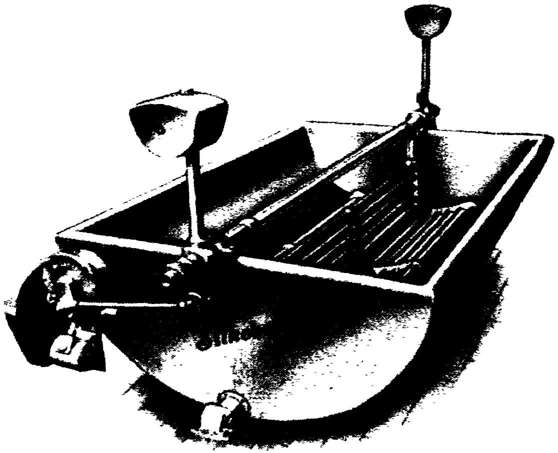


Fig. Cr 2.—*Ageing Vat for Cream.*

[*Photos by courtesy of Hiron & Rempler Ltd.*

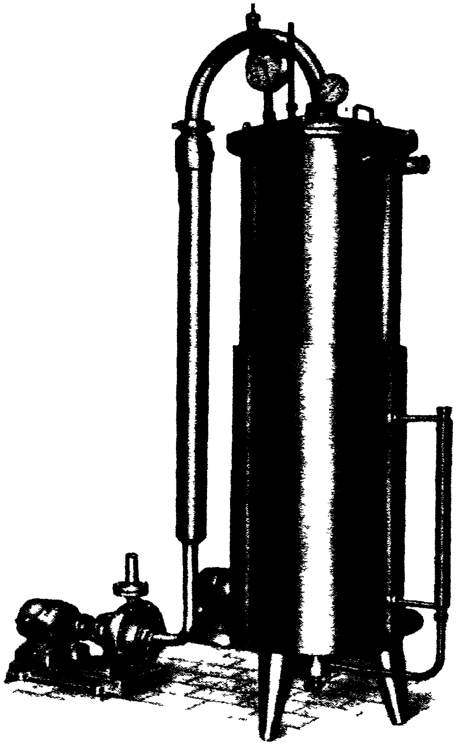
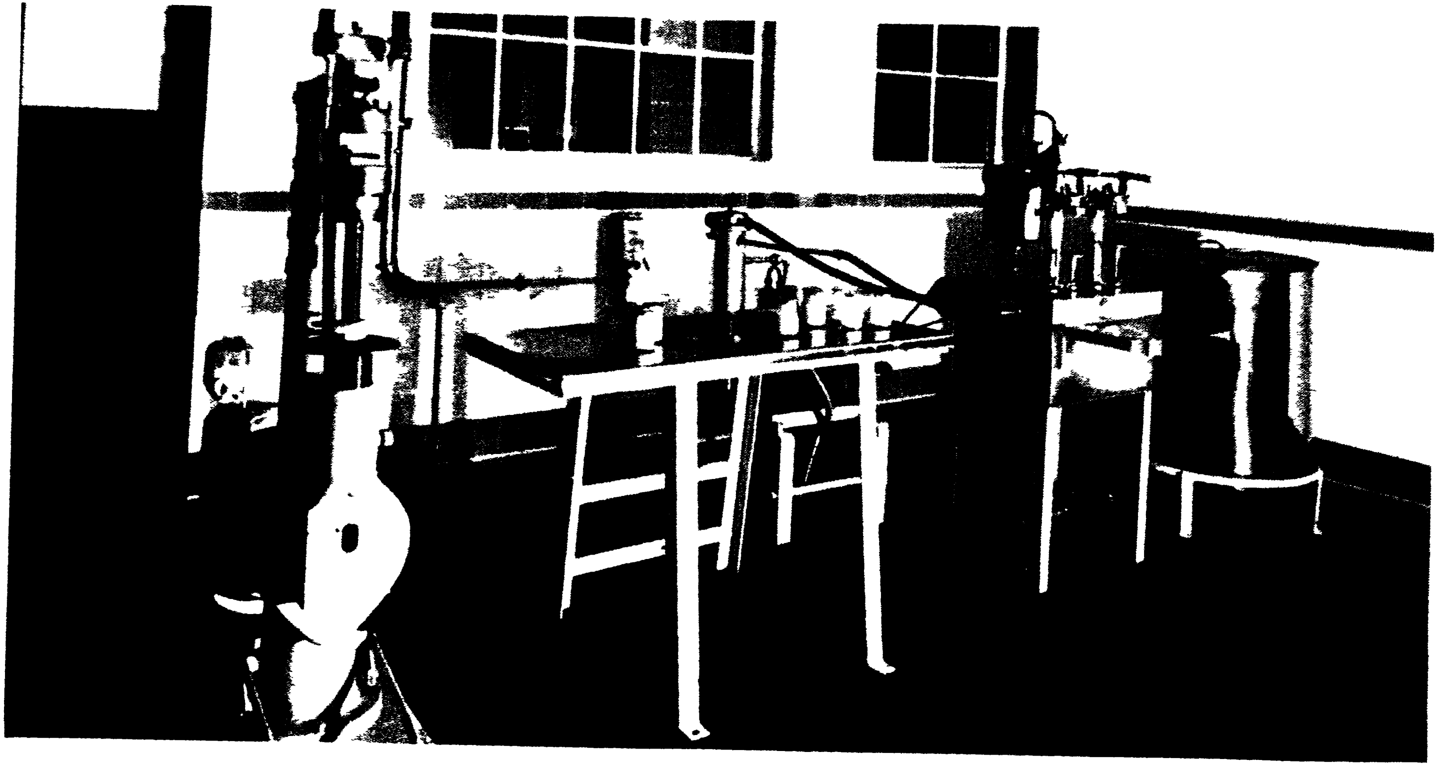


Fig. Cr 3.—*Vacumator-aggregate Deodorising Cream.*



[By courtesy of United Dairies Ltd

FIG Cr 4 —*Filling Cream into Bottles*

A centrifugal pump is not permissible for cream and one must, therefore, use a rotary pump or use a homogeniser as a pump.

A taint due to hydrogen sulphide is sometimes noticeable in imported cream. The best method of eradicating this defect is vacreation.

Viscosity. Viscosity may be increased by ageing at 36° to 38° F. and practically all the increase that is obtained is acquired in the first 24 hr.

Re-embodying. This is popular in U.S.A. and is brought about by re-heating slowly to 85° F., taking over 1 hr., holding at this temperature for 10 min., and then cooling over a period of 1 hr. to 60° F. It is now realised that this lengthy process is not necessary and cream is now heated to 85° F. in 10 min. and cooled to 40° F. in 15 min. Better results are obtained if low temperature heating is used.

An alternative method is to pasteurise the milk, hold at 40° and then separate at 80° F. and sell without further heat treatment. This method is, of course, attended by serious danger of bacterial contamination. The use of a plate heat exchanger always lowers the viscosity of cream. Manipulation of cream under certain conditions may lead to churning. A solid mass is more likely to be obtained with a low temperature heating method.

Homogenisation. Homogenisation should take place at 120° F. There is a period of instability over the temperature range 130° to 155° F. Two-stage homogenisation is best, as the homogenised globules tend to cluster and the second low pressure homogenisation breaks up these clumps.

The viscosity of homogenised cream increases with increasing pressure of homogenisation.

Keeping quality. This is usually a major factor in commerce ; and a minimum of 3 days should be attained at summer temperatures. This requires a maximum bacterial count of 2000 and the count should preferably be under 1000. The usual trouble is souring, and micrococci and especially coli are usually the cause. The next most common trouble is bitterness and this fault occurs without warning. It is usually due to *B. subtilis*, which is very heat resistant. The best results are obtained by the H.T.S.T. method, especially by double heating. The counts after this should be reduced to 500 per ml. or less.

The chief trouble is experienced in filling and this is the chief source of coli. Contamination in filling may halve the original keeping quality, and it is always best to heat and cool in the retail container if possible. Refrigerated transport would be invaluable for cream but this is not yet generally adopted in this country.

Provided the initial bacteriological condition of the cream is good and heat-treatment given, chilled cream can be stored for up to five days in perfect safety. Ordinary cans can be used for this purpose. As with pasteurised milk, it is better to fill the cream directly into the final retail containers and store in these. The " cooked " flavour is less noticeable when the holder method is used, but differences between the two methods are very slight. If cream is heated to above 145° F. the viscosity is reduced. Clumping takes place best at 45° F. and does not take place at over 145° F. The best results are obtained by very gentle agitation and very slow cooling from 90° F. down to 40° F. This is awkward under ordinary processing arrangements and hence cream is commonly filled out at 60° F. and cooled in the final containers to 40° F.

The bacterial content of cream is about the same as that of the milk used (per ml.). Some workers have found that lower counts are obtained in cream.

It is illegal to add any preservative to cream. Before 1926 it was customary to add 0·5 per cent. boric acid.

Fig. Cr 1 shows the pre-heaters, separators, cooler and storage vats in a modern factory. Fig. Cr 2 shows the coils in an ageing vat and Fig. Cr 3 a vacuum type de-odoriser. Fig. Cr 4 illustrates the filling of cream into bottles.

Yield. The yield of cream from milk denotes the amount of cream by weight which can be obtained from a certain weight of milk. This is given either as a percentage, or as an actual figure in pounds weight. The formula given below can be used to determine the theoretical yield of cream from milk.

$$C = M \times \frac{f - f_1}{f_2 - f_1}.$$

Where C = lb. weight of cream obtainable from the milk ; M = lb. weight of original milk ; f = fat content per cent. of the original milk ; f_1 = fat content per cent. of the skimmed milk ; f_2 = fat content per cent. of the cream obtained.

As an example, if we had 50 lb. of milk with a fat content of 3·6 per cent. and skimmed it until the fat content became 0·1 per cent., then the amount of cream with a fat content of, say, 61·0 per cent. which should be obtained is :

$$50 \times \frac{3{\cdot}6 - 0{\cdot}1}{61{\cdot}0 - 0{\cdot}1} = 2{\cdot}87 \text{ lb. of cream.}$$

This formula is often useful in tracing unnecessary waste of cream. *See* Butter ; Cream, canned ; Fat ; Fat globules ; Homogenisation ; Management of creameries ; Separators.

Refs. : Hunziker (B) ; Rogers ; Totman, McKay and Larson ; Richmond ; Davies ; Roberts *et al.* (1953), *MPM*, **42**, (6) 19 (viscosity and whipping) ; Crossley and Cuttell (1953), *IDC*, **2**, 481 (heat treatment) ; Dolby (1953), *JDR*, **20**, 201 (heat treatment on globules) ; Hooley (1953), *DI*, **18**, 676 (heat treatment); Crossley (1948), *JDR*, **15**, 261 (bacteriology) ; Herreid *et al.* (1952), *JDS*, **35**, 13 (effect of heat) ; Claydon and Foltz (1951), *JDS*, **34**, 11 (yeastiness) ; Mohr and Wellin (1948), *M*, **3**, 149, 181 (viscosity) ; Smillie (1949), *JSDT*, **3**, 23 ; Killick (1949), *IDC*, **1**, 405 (quality payment).

CREAM, CANNED. Canned cream is a sterilised product, fundamentally similar to evaporated milk, and normally produced on a large scale in specialised factories.

Raw milk reception entails careful control of bacteriological quality and heat stability, as for evaporated milk (p. 288). The cream is separated at about 50 per cent. fat content and standardised to the desired fat content by addition of separated milk. Canned cream usually contains 23 to 28 per cent. fat, and the Ministry of Food in 1951 introduced a minimum standard of 23 per cent. fat ; but before the recent war, cream sterilised in glass bottles with hermetic metal closure (usually a crown cap with rubber ring), was produced containing up to 45 per cent. fat. This is about the maximum without fat separation during sterilisation, which renders the product oily and unpalatable. Rapid, continuous handling of the cream is essential to prevent bacterial proliferation which may introduce dangerous numbers of heat-resistant species ; if this is impossible, the cream must be pasteurised and cooled immediately after separation. The titratable acidity of the standardised cream should not exceed 0·15 per cent. otherwise the sterilised product may be " grainy " in texture.

As in evaporated milk, low heat stability may occur resulting in a hard, granular coagulation of the casein. In addition, pronounced age thickening of the sterilised product always occurs during storage. Initial thickening is very rapid during the first three weeks after manufacture, followed by slower thickening to an almost solid consistency. This difficulty may be reduced by addition of a stabiliser. Sodium bicarbonate (about 1 oz. per 6 gal. of cream) produces a rather thick product of dark colour. Trisodium citrate (1 oz. per 10 gal. of cream) gives a much lighter colour and a thin consistency, and is now most commonly used. There is, however, no uniformity of practice. Many manufacturers in Britain use smaller quantities of stabiliser or often none at all, but are able to obtain a smooth texture and satisfactory viscosity. Experimental pilot runs may be employed, but are only justified at seasonal periods of instability.

The standardised, stabilised cream must next be homogenised. This is essential to prevent fat separation during sterilisation and to regulate the viscosity. The cream is preheated before homogenisation, the choice of preheating temperature being important. The minimum temperature to ensure a smooth sterilised product is about 158° F. but 175° F. is preferable. Cream homogenised at 145° F. may coagulate in 30 min. at 245° F., which leaves a rather small margin during the sterilising process. Homogenisation varies between (*a*) single homogenization in a two-stage machine at 2500–4000 lb. per sq. in., or (*b*) homogenisation at 2500–3000 lb. per sq. in. followed by a second homogenisation at 500 lb. per sq. in. It is a safe rule to use the lowest pressure which yields the desired viscosity; this varies slightly, especially seasonally. Double homogenisation is claimed particularly to reduce " feathering " (formation of a flaky surface coating on hot coffee) a defect of little moment in Britain but much disliked in the U.S.A. and Holland. In general, cream viscosity (and also feathering) is reduced by (*a*) low acidity of cream, (*b*) addition of stabiliser, (*c*) high temperature preheating around 175° F., (*d*) low homogenisation pressures. It is advisable to adjust these factors to produce a rather thin fresh product in order to counterbalance age thickening, depending upon the normal period of distribution and sale and upon local preferences in respect of viscosity (this factor is quite variable in Britain).

The homogenised cream is filled into standard type cans with double-seamed cover. Common sizes are 3 oz. and 6 oz., but sizes up to 36 oz. have been used. The filled, sealed cans are passed by conveyor to the sterilising room. The objective is the same as for evaporated milk (*viz.* sterility) and the same plant is used—either the batch type retort or the continuous automatic steriliser. The latter is rarely economic with the outputs possible in Britain. Cooling is also carried out as for evaporated milk, and indeed canned cream and evaporated milk are often produced at the same plant. The exact process of sterilisation is, however, rather variable in Britain, differing between various manufacturers and with size of can. Examples are: (*a*) 237° F. 25 min. (3 oz. can) or 30 min. (6 oz. can); (*b*) 241° F. 20 min. (3 oz. can) or 25 min. (6 oz. can); (*c*) 235° F. 20 min. (3 oz. can) or 25 min. (6 oz. can) followed by a rapid rise to and holding for 4 min. at 246 F. (3 oz. can) or 248° F. (6 oz. can). In the U.S.A. practice seems to have become widely standardised at 244° F. for 12 to 15 min. When glass bottles closed by a metal cap with rubber ring are used, an upright stationary retort is employed. Lower temperatures and longer holding times are also usual, *e.g.* 2 to 4 oz. bottle 225° F. 45 min.; 8 oz. bottle 230° F. 55 min. Cooling of bottled cream must also be commenced with hot water to avoid fracture of the glass.

Skilled laboratory control is essential to successful manufacture. Canned cream is bacteriologically almost identical with evaporated milk, and is not necessarily sterile. The major defect in Britain is the development of a bitter flavour accompanied by " thinning " of the cream, owing to the growth of specialised strains of *B. subtilis*, which form very heat-resistant spores. Nichols (1938) isolated *B. subtilis* strains capable of surviving at 248° F. for 40 min. Investigation of this defect is hampered by the difficulty of reproducing it in the laboratory. The presence of these organisms in numbers sufficient to produce a high proportion of defective cans may be attributed to (*a*) small numbers originating from particular raw milk supplies, (*b*) inefficient cleansing and sterilisation of plant, resulting in the presence of large numbers of spores in the cream *before* sterilisation, (*c*) inadequate heat treatment or inaccurate thermometers. Trouble is often overcome by close attention to plant hygiene and specially stringent sterilisation of all equipment. In addition, the real heat treatment received by the *cream* should be determined by thermocouple measurements of the temperature at the centre of the can. Heat penetration of cream is slow, particularly in the larger can sizes. Only if these measures prove unavailing should consideration be given to a temporary increase in the temperature or time of sterilisation—the former is usually more effective. Blown cans resulting from the survival and development of spore-forming anaerobic bacilli occur very occasionally, but their incidence is rather surprisingly small.

As in the case of evaporated milk, cooling water leakage into defective cans may lead to the presence of a wide variety of organisms. A large proportion of defective cans is due to this cause, which is recognisable by the predominance of non-spore-forming organisms. The most usual effects are acid curdling (mainly cocci) or acid curdling with gas production (usually cocci with coliform organisms). Primary control depends upon rigorous checking of can seaming at regular intervals—preferably every 30 min.—and as a secondary precaution consideration may be given to chlorination of the cooling water, although this alone is rarely adequate. It should be remembered that the majority of leaks occur at the seam which is closed by the cream manufacturer.

Whatever their source, the number of organisms present in the product immediately after manufacture is normally extremely small, and the standard methods of examination, *e.g.* plate colony count, are almost valueless. Non-sterile cans may be demonstrated by either (*a*) inoculation of large quantities (at least 10 ml.) of cream into a suitable liquid enrichment medium, preferably sterile milk plus indicator or glucose broth, and incubation at 30° C. for 4 days, or (*b*) preliminary incubation of the can at 30° C. for 10 days, followed by inoculation of 1 ml. quantities into liquid media and yeastrel milk agar plates, and incubation at 30° C. for 4 days. Care must be taken to observe strict aseptic precautions when opening the can. No batch of cans should be released for distribution until it is known to be bacteriologically satisfactory. Incubation of the whole batch of cans at 85° F. may also be practised. After two weeks the majority of faulty cans are detectable by inspection or shaking, but some require longer incubation before this is possible. In addition to bacteriological supervision, control of chemical composition and standardisation is of obvious importance.

A few other matters may be the subject of consumer complaints. Thus, some cooked flavour is inevitable, but this should not be excessive and the heat treatment should be kept down to the bacteriological minimum; these two considerations tend to clash, especially with large containers. Body and texture also require careful control by the methods previously described. Viscosity tests immediately after manufacture and again after 14 days' storage at 85° to 90° F. yield useful information; some degree of age thickening is unavoidable. It is not always possible to avoid a very slight grainy texture and serum separation which is readily reincorporated by shaking the container before opening. Consumers object, however, to large hard lumps and much serum resulting from inadequate control of heat stability. A purple, or occasionally black, feathery pattern on the inside of the container may produce complaints. When it occurs, this discoloration is present immediately after manufacture, affects the whole batch, and is extremely difficult to control. Fortunately the trouble usually proceeds no further, but after several months some individual cans develop severe corrosion and black specks on the surface of the cream. This attack is due to liberation of sulphydryls from the proteins during sterilisation, which react with the container to form sulphides of tin and iron. Purpling is not influenced by cream acidity or the volume of air space, but is accentuated by the presence of colostrum in milk supplies and the use of poor quality tinplate. The major factors, however, are the time and temperature of heating and the use of citrate stabiliser. All of these should be reduced to a minimum, but this may well conflict with bacteriological requirements and production of the desired body and texture. For details see Jackson *et al.* (1936) and (1937). *See* also Cream; Evaporated milk (p. 288); Homogenisation; Packaging; Stability.

Refs.: King (1953), *M*, **8**, 251 (stability); Nichols (1938), *Hannah Dairy Res. Inst.*, Rep. 75; (1939), *JDR*, **10**, 231; Nichols *et al.* (1937), *JDR*, **8**, 331; Jackson *et al.* (1936), *JDR*, **7**, 284; (1937) **8**, 324; King (1949), *IDC*, **2**, 36.

CREAM CHEESE. *See* Cheese, pp. 190 and 200.

CREAM, CULTURED. A culture of *Str. lactis* and other lactic acid bacteria in homogenised low-fat cream.

Refs.: Whittier and Webb ; Guthrie (1952), Bull. Cornell Agr. Exp. Sta. 880.

CREAM, DRIED. Dried cream is not prepared in this country, but in America small quantities are made for special use for the bakery and confectionery industries.

Ref.: Whittier and Webb.

CREAM LAYER OR LINE. The fat, being lighter than milk, slowly accumulates at the surface to form the cream layer, commonly called the cream line. The introduction of the glass bottle inevitably led to the importance of cream line as a " sales point " and so automatically acted as a break on the over-pasteurisation of milk (p. 793).

The following factors control the rate of formation and depth of cream layer: (*a*) percentage of fat in milk ; (*b*) size of fat globules ; (*c*) temperature of milk ; (*d*) overheating the milk ; (*e*) agitation, especially when cold or hot.

The colour of the fat (carotene content) does not affect the depth of cream layer but makes it more obvious to the eye.

The formation of the cream layer in milk depends upon the speed with which the fat globules rise to the top, and the thickness of the layer depends upon the degree of clustering of the globules. If the globules do not cluster, they rise more slowly and pack more closely so that a poor creamline is formed only after some considerable time. If there is a considerable amount of clustering, the cream layer is formed quickly and is much more bulky on account of the looseness of packing.

The velocity of rise of a fat globule will be proportionate to the square of its radius when the other factors are constant. This explains why creamline forms rapidly with Guernsey and Jersey milk. (*See* Fat globules; Stokes' law.)

With other milks in which the fat is present as smaller globules, the rate of formation of creamline will be enhanced by the clustering of the globules, as a cluster of globules behaves, from this point of view, like one large globule, but will have the added advantage that the looseness of packing will increase the volume of the cream layer. In practice the degree of clustering is the dominating factor in the creaming properties of the milk. Rahn ((1921) *Milchw. Forsch.*, **1**, 133, 165, 213 ; (1922) *Koll. Z.*, **30**, 110) measured the velocity of single globules and clusters in milk and showed that the single globules rose so slowly that 50 hr. would be required for the fat to rise from the bottom to the top of the vessel. Clusters rise much more quickly, and the addition of such substances as gelatin and gum arabic increases cluster formation and so accelerates the rise of the fat.

Various theories have been put forward from time to time to explain the formation of the cream layer and especially to account for the clustering of fat globules. The most important theories have been those based on chance contacts due to differences in rates of movement, electro-kinetic potentials, interfacial tension and the adhesive nature and state of hydration of the adsorbed membrane of the globule.

The theory which is generally accepted today is that commonly called the " agglutinin " theory, and the experimental evidence for this is now considerable. Van Dam and Sirks (1922, *Verslag. landb. onderzoek. Rijslandbouw*, **26**, 106–86) showed that the creaming properties of milk could be improved by the addition of blood serum provided the serum had not been heated to 65° C. or over. Further experiments (Hekma and Sirks 1923, *Proefsuivelboerderij*, Hoorn, 88–103) showed that blood serum could be heated to 60° C. without affecting the creaming properties, but that above 62° C. creaming was affected. It was then realised that the substances responsible, and presumably destroyed by heating at a certain temperature, were similar to bacterial agglutinins, and it was found that the substance responsible was precipitated with the globulin fraction. Further fractionation separated the euglobulin and pseudoglobulin, and showed that the former, but not the latter, was effective for milk fat globules. When the fat globules were separated from milk by centrifuging warm, washed and pasteurised at 90° C. for 5 min., creaming could still be obtained on addition of the unheated separated milk. These experiments proved, therefore, that the clustering of the fat globules and the creaming of milk are due to specific chemical substances which can be destroyed by heat.

Various experiments which have since been made have all confirmed this basic theory. Thus, agglutinins, being of a globulin nature, are found in whey (Palmer *et al.*, 1926, *JDS*, **9**, 171–91; Troy and Sharp, 1928, *JDS*, **11**, 189–229). Colostrum is rich in globulin and as little as 1 per cent. of colostrum can improve the creaming properties of heated milk. Orla-Jensen at this time pointed out that agglutinins in milk did not result in any attraction between the globules but merely enabled them to stick together after contact had been made. Rowland (1937, *JDS*, **8**, 195–202) also showed that the reduction of creaming powder was proportionate to the percentage denaturation of the globulin in milk.

An important experimental advance was made by Sharp and Krukowsky (1939, *JDS*, **22**, 743–51) who showed that the agglutinins were adsorbed on solid but not on liquid fat globules. Thus, if milk is separated at low temperatures the agglutinin is concentrated in the cream and is almost entirely absent from the separated milk, but if separation takes place at high temperatures little agglutinin remains in the cream, but a large amount comes away with the skim milk. Thus, agglutinins can be concentrated by separating the cream first at a low temperature and then at a high temperature. The liquid obtained by the second centrifuging is very rich in agglutinins.

Detailed studies of the nature of agglutinating effect have been made by Dunkley and Sommer (1944, *Agric. Exp. Stat. Univ. Wisconsin Research Bull.*, 151). They separated milk first at 10° C. and then at 50° C. They showed that although increasing concentrations of agglutinin material affected the cream volume no difference could be observed in the electro-phoretic mobility of the fat globules. They concluded that only gravity was, therefore, a factor in the clustering effect and that differences in electro-kinetic potentials at the surface of the fat globule were not a factor.

The addition of a surface active material, such as sodium alkyl sulphonate, first increases and then decreases the creaming properties of the globules. The addition of acid results in a fall in both the cluster index and the cream volume.

The stickiness theory was studied by the addition of gelatin and sodium alginate, and although these had no marked effect on the cluster index they both retarded the rate of creamline formation, but increased the final volume of the cream layer.

The addition of alcohol produced a large increase both in the rate of creaming and in the thickness of the cream layer, but the cream volume diminished on standing.

Comprehensive studies of Dunkley and Sommer have shown that theories other than the agglutinin theory are without any substantial experimental evidence. They have studied the various factors concerned in the agglutinin process:

(1) ***Effect of ageing at low temperature.*** Milk which is aged at a low temperature loses its creaming ability but the original creamline can be restored by warming the milk to from 50° C. to 60° C. for a short time. By their technique of separating and treating separately the fat globules and the agglutinin-rich fraction they showed that it is necessary to warm only the agglutinin-containing portion. Thus, only the skim milk need be warmed for this purpose. If the cream is warmed also the liquefaction of the fat results in a smaller cream layer.

It appears that at low temperatures the agglutinin undergoes a physical change and it has been observed that when portions containing high concentrations of agglutinin are held at room temperature some of the protein flocculates.

To see if this change in agglutinins is responsible for the difference in surface tension of milk warmed to 25° C. compared with when milk is cooled to 25° C. as reported by Sharp and Krukowsky, the samples were aged and warmed, and it was found that the change in surface tension is associated with the physical state of the fat and not with any change in the agglutinin.

(2) ***Effect of dilution.*** It has been known for some time that dilution of milk with water favours the formation of cream layer. Orla-Jensen (1928, *Proc. World's Dairy Congr.*, 107–23) suggested that this was due to the dilution of the salts which hindered the action of the agglutinins. The maximum cream layer is obtained at about 50 per cent. dilution, the cream volume decreasing rapidly at higher dilutions.

(3) ***Effect of protein precipitants.*** Salts which precipitate protein also prevent or retard cream layer formation. Thus, the most active salts in this respect are ferric chloride, aluminium chloride, calcium chloride and sodium chloride. Sodium citrate and di-sodium phosphate are virtually without effect on creamline.

(4) ***Effect of homogenisation.*** Mertens (1932, *Milchw. Forsch.*, **14**, 1–20, 21–32, 33–6, 37–40) observed that milk formed from normal cream and homogenised skim milk does not give a cream layer. Dunkley and Sommer have shown that pressures, even as low as 100 lb. per sq. in., can cause marked reduction in creaming properties. They explain this as being due to the denaturation of the agglutinin by the violent agitation received during homogenisation.

However, cream line can be improved by homogenisation of the cream only (Wilcke (1953), *M* **8**, 230).

(5) ***Effect of heating.*** Dunkley and Sommer (1944, *Agr. Exp. Sta. Univ. Wis. Bull.*, 151) have heated skim milk for 30 min. at various temperatures and shown that at temperatures above 145° F. there is a drastic effect on creamline: thus a temperature of 147° F. effectively prevented the formation of a cream layer after 1 hr.

(6) ***Effect of casein.*** Palmer *et al.* (1926, *JDS*, **9**, 171–91) observed that whereas whey proteins favoured creaming, casein appeared to hinder it. Experiments by Dunkley and Sommer (1944, *Ag. Exp. Sta. Univ. Wis. Bull.*, 151) have shown that agglutinins in whey behave in exactly the same way as those from skim milk and good creaming can be obtained with a milk made by recombining cream with whey containing agglutinins. Some interesting differences were observed in the agglutinin-rich and agglutinin-poor wheys. When the first was allowed to stand undisturbed part of the protein appeared to flocculate but did not actually precipitate. This flocculation was not seen in the agglutinin-poor whey. Storage at 5° C. gave a rich sediment in the agglutinin-rich whey but little or none in the poor whey. Milk made by recombining cream with the suspension of sediment had very marked creaming properties whereas that made using the upper clear whey creamed only very poorly.

(7) ***Concentration of agglutinin.*** Milk containing solidified fat was separated and the cream washed rapidly with cold water. This gave a cream very low in solids-not-fat but rich in agglutinin. By separating this cream at 50° C. a serum was obtained with a relatively high concentration of agglutinin. The same sediment and flocculation were observed with the agglutinin-rich whey.

The serum was then fractionated to separate the proteins according to the method of Howe (1922, *J. Biol. Chem.*, **52**, 51–68). A large proportion of the protein of the washed serum was present in the euglobulin fraction. A typical experiment is illustrated in Table CL I and Dunkley and Sommer showed that the euglobulin suspension had exactly the same cream layer forming properties as the washed cream serum.

Orla-Jensen has made an interesting observation that agglutinin does not cause fat clustering in a mixture of 50° C. cream and water made up to imitate milk, and this observation was confirmed by Dunkley and Sommer for their euglobulin fraction. It is necessary to have some 10 per cent. skim milk to promote the clustering. It appears that the constituent of the skim milk necessary is one or more of the salts present. Experiments with various salts showed that calcium chloride, sodium citrate and disodium phosphate all favoured cream layer formation but that calcium chloride was significantly the best salt in this respect. At higher concentrations aluminium chloride decreased cream volume.

TABLE CL 1

DISTRIBUTION OF PROTEINS IN WASHED CREAM SERUM

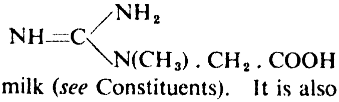
	% Protein	*% of total protein*
Washed cream serum	0·0467	100 0
Second wash water	0·0097	20·7
Agglutinin (by difference)	0·0370	79 3
Euglobulin	0·0353	75·7
Casein	0·0037	7·9
Pseudoglobulin I	0·0002	0 4
Pseudoglobulin II and albumin	0·0066	14·1
Residual	0·0009	1·9

Studies on the behaviour of euglobulin indicated some apparent irregularities, particularly in respect of its colloidal behaviour (compare also Marrack (1938), *Med. Res. Counc. Spec. Rept. Ser.*, 230). Drying treatment resulted in some loss of fat clustering power but all samples showed pronounced fat clustering properties. *See* Agglutinins; Fat globules; Stokes' law.

Refs.: Davies; Richmond; Rogers; Fahmi (1951), *JDR*, **18**, 106 (buffaloes' milk); Hannson (1949), *IDC*, **2**, 30; Sharp (1940), *JDS*, **23**, 771; Palmer and Tarassuk (1940), *JDS*, **23**, 861; Cuttell (1945), *DI*, **10**, 555.

CREAM LINE INDEX. A figure or ratio obtained by dividing the percentage cream line (layer) by the percentage of fat in the milk. For ordinary bulk pasteurised milk in England (mainly Shorthorn or Friesian) the cream line is usually about 6 per cent. and the cream line index about 1.7. Channel Islands milk gives higher values. Ref.: *Milk testing.*

CREAMERY LABORATORY. *See* Laboratory.

CREATINE. Creatine is  $$\mathrm{NH{=}C}\begin{matrix}\diagup \mathrm{NH_2}\\ \diagdown \mathrm{N(CH_3)\,.\,CH_2\,.\,COOH}\end{matrix}$$ and occurs in traces in milk (*see* Constituents). It is also of interest in that it is essential for the Voges-Proskauer reaction (p. 263) one of the most important diagnostic tests for differentiating the *aerogenes* from the true *coli* bacteria (p. 266).

CRISMER TEST. A test for the chemical nature of butter and other fats depending on the solubility of the fat or oil in alcohol (Crismer, 1895, *A*, **20**, 209) and later modified by Fryer and Weston (1918, *A*, **43**, 3).

CROWDY. A mixture of meal and water resembling porridge used for feeding animals. *See* Fallacies; Feeding.

CRUSTLESS CHEESE. *See* Processed cheese, p. 199.

CRYOLAC NUMBER. A number related to the theoretical freezing-point calculated from the lactose and chloride content of the milk (Post (1926), *BCA*, **1**, 846B) and varying from 393 to 435 (mean 413) for genuine milk (Fiehe and Kordatzki (1928), Z. Unters. Lebensmitt., **55**, 251 and *BCA*, **3**, 687B).

CRYOHYDRATE. A substance which in solution solidifies as a whole.

CRYOHYDRIC POINT. The temperature at which a cryohydrate solidifies Thus for sodium chloride solution, – 22° C.; for calcium chloride, – 55° C.

CRYOSCOPY. The science of determining the freezing-points of liquids. *See* Freezing-point test.

CULLET. Broken glass; in dairying referring to broken bottles.

CULTURAL REACTIONS. *See* Classification; Coliforms; Lactic acid bacteria; Propionic acid bacteria.

CULTURE MEDIA. *See* Media; Classification; Coliforms; Lactic acid bacteria; Mastitis.

CULTURES, PRESERVATION OF. Acid-forming bacteria are of considerable significance in the study of milk, and the lethal effect of hydrogen ions involves frequent sub-culture of laboratory strains.

The most convenient way of preserving such cultures is to inoculate them into litmus milk (or reinforced litmus milk) containing 3 per cent. pure precipitated calcium carbonate, previously sterilised. The cultures are incubated at the optimum temperatures for growth of the particular strain (22° to 45° C.) and when visible growth has taken place (usually acid formation takes place in 1 to 2 days) removed and held at room temperature. McCartney screw-cap bottles are superior to plugged test-tubes for this purpose, as evaporation and reoxidation of the litmus are reduced to a minimum. For the more aerophobic species, large inocula and recently heated and cooled media should be used. Liquid paraffin or vaseline may with advantage be added. With this chalk-litmus-milk method such poorly viable types as *Str. thermophilus* and *L. bulgaricus* have been found to remain viable for about 3 months and *Str. lactis*, *Str. cremoris*, and *L. casei* remain viable under these conditions for about a year. An alternative method is to make stab cultures in 0·5 per cent. dextrose agar containing 1 per cent. chalk " emulsified " in the medium or plain 0·2 per cent. dextrose agar. *See* Classification; Freeze-drying; Lactic acid bacteria.

Ref.: Cowan (1953), *LP*, **2**, 641.

CULTURED MILKS. This term broadly includes all the soured and fermented milk drinks. *See* Acidophilus; Bulgaricus; Yoghurt; Kefir; Matzoon; Lactic acid bacteria; Ymer.

Refs.: Burke; Hammer; Orla-Jensen; Rogers.

CURD. The soft rubbery solid formed when milk is clotted by rennet (p. 902) or acid.

In cheesemaking (p. 168) the term is usually reserved for the material from the time of cutting up to the time of putting to press. *See* Rheology.

CURD TENSION. The strength of curd produced from a milk and measured under standardised conditions. It is used more in U.S.A. where particular attention is paid to the digestibility of milks from different cows and herds. (*See* Soft curd milk.)

The most important factors are the acidity or *p*H and the concentration of calcium ions. Milk which has been heated much above 150° F. gives a weaker curd.

Hill's method (1923, *JDS*, **6**, 509) uses a special knife which is drawn up through the pepsin-calcium chloride coagulum by means of a spring balance. Average milks give values from 50 to 90 g.; to be classified as a " soft curd milk " the tension must be less than 20 g.

Ref.: Rogers.

CYTASE. An enzyme dissolving cellulose.

CZECHOSLOVAKIA.

Ref.: Proks (1949), *IDC*, **4**, 521.

D

DADHI. A fermented milk of the yoghurt type.

DAIRIES, LARGE, DESIGN OF. Before attempting to design a dairy or to consider a general arrangement of the dairy plant (Dierickx 1949, Farrall 1949, Horne 1949, and Matthews 1948), the person responsible (it will be here assumed to be the dairy manager) for the construction of the building and installation of the plant should have a clear conception of the immediate capacity required and, what is equally important, the ultimate capacity desired. When planning alterations to an existing building these requirements should be equally well understood.

The need for care in planning for the future seems to be very real, as many dairies appear to have been erected with little thought to the manner in which extra capacity can be obtained at minimum cost and minimum disturbance of the business carried on during alterations.

Before proceeding to formulate any definite plans, the dairy manager should consider forming a working committee of those responsible for advising him, in connection with their special departments, on the construction and equipment of the dairy. The composition of such a committee will vary, but probably will include the following:

(*a*) ***Engineer.*** His function will usually consist of exercising an over-riding supervision and co-ordination of all work of installation by engineers and plant engineers, as well as work performed by his own department.

(*b*) ***Transport manager.*** He should advise on yard space required, garage accommodation, transport, workshop accommodation, the height of loading and unloading banks, and methods of loading and unloading. His advice on cold storage capacity and area of loading banks should also be of value.

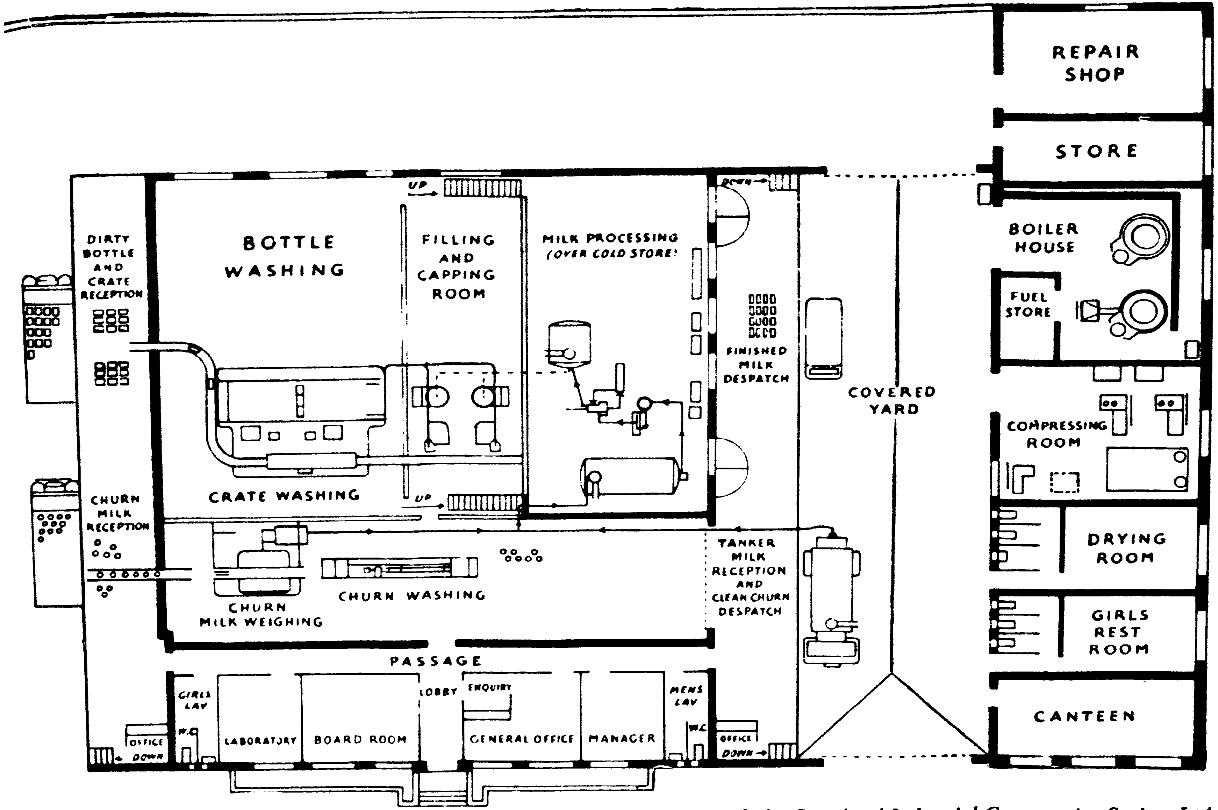
(*c*) ***Head of laboratory.*** He should assist in determining the space required for, and the position of, the laboratories. He should also provide particulars of the layout required, and heating and ventilation; also arrangement of the service of gas, water, and electricity for lighting and power in the laboratories. His opinion should also be sought on any matters affecting hygiene.

(*d*) ***Architect.*** In addition to the usual duties of an architect, his main responsibility should be to adapt building practice to the needs of the final layout, and construct a suitable building around the plant.

It will be necessary in most cases for the dairy manager to consult with other professional services (see p. 641), but the sections mentioned above appear to be essential. When such a committee is in being, no major discussions should take place outside the committee, all members of which should be kept fully informed on all matters relating to the project.

Having established the initial and future capacity required, the site, if a new building is to be erected, should be chosen after careful consideration of the following points in consultation with the retail side of the business: (1) Geographical position in relation to distribution depots. (2) Facilities for rail siding accommodation and accessibility to the necessary railway systems. (3) The availability of essential services such as power, water, gas, drainage, and sewers. (4) The possibility of causing a nuisance, by reason of noise, to residents in the vicinity. (5) The condition of the site and cost of preparation. (6) The advisability of selecting a site capable of giving road access to all sides of the building.

Having decided on the site, the fullest use should be made of the committe in both general discussion and suggestions, and in matters of detail. Their



[By courtesy of The Gateshead Industrial Co-operative Society Ltd.

FIG DLD 1.—*Ground Floor Dairy.*

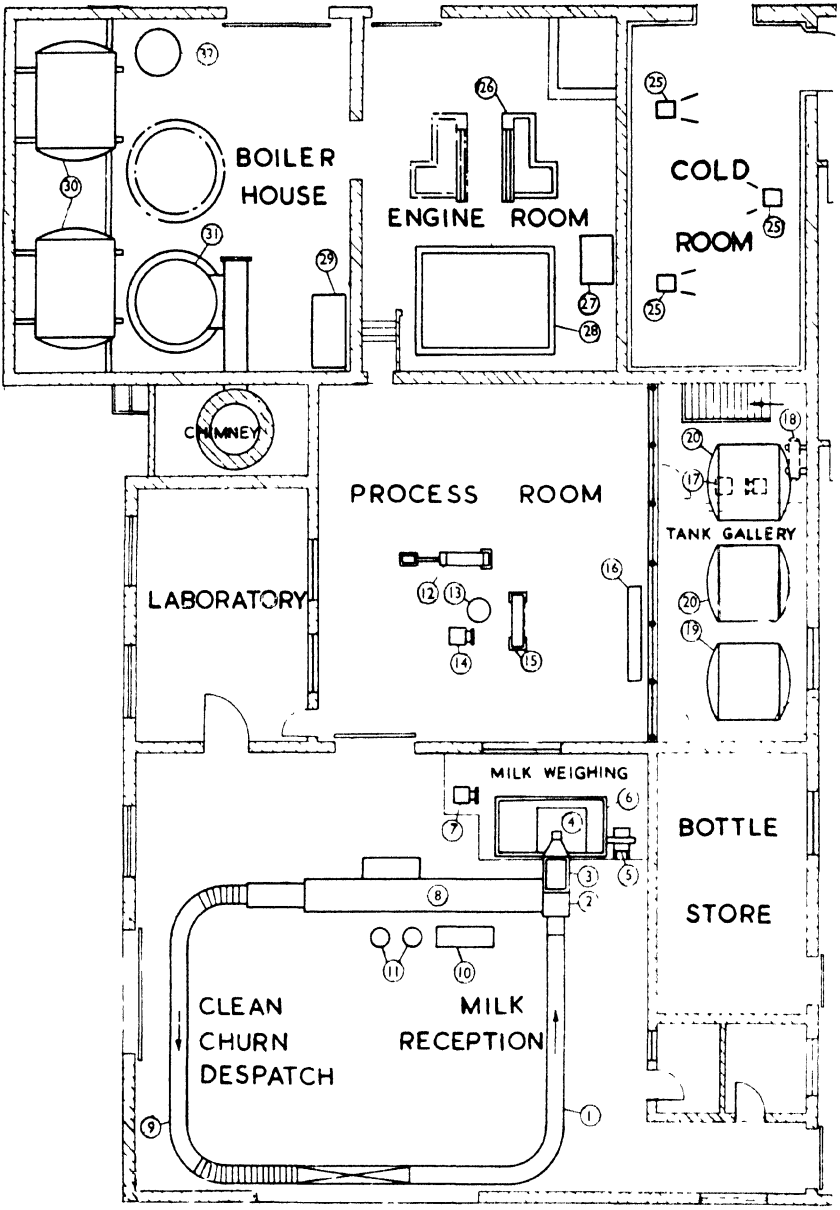
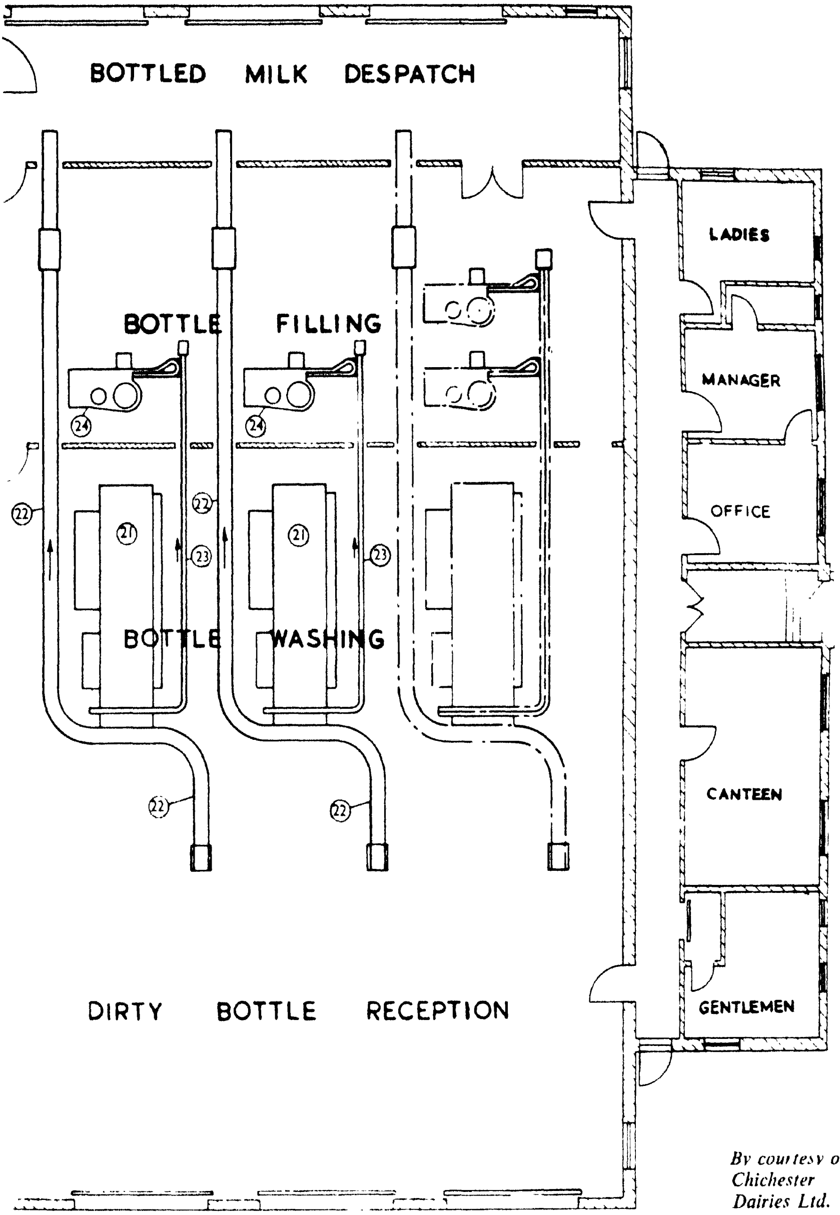


FIG. DLD 2.—*A ground*

(1) *Power Churn Conveyor.*
(2) *Churn Tipping Block.*
(3) *Milk Dump Tank.*
(4) 100 *gal. Weigh Bowl.*
(5) *Avery Weighing Machine.*
(6) 500 *gal. Milk Receiving Tank.*
(7) *Primary Raw Milk Pump.*
(8) *Str.-Through Churn Washer.*
(9) *Gravity Churn Conveyor.*
(10) *Churn Washing Trough.*
(11) *Churn Steaming Blocks.*
(12) *H.M. Type Paraflow.*
(13) *Float Controlled Balance Tank.*
(14) *Secondary Raw Milk Pump.*
(15) *Control Panel.*
(16) *Pipe Washing and Sterilising Chest.*



By courtesy of Chichester Dairies Ltd.

floor arrangement.

(17) *Hot Water Circulating Set.*
(18) *Air Compressor.*
(19) *Raw Milk Storage Tank.*
(20) *Finished Milk Storage Tank.*
(21) *Bottle Washer.*
(22) *Case Conveyor.*
(23) *Bottle Slat Conveyor.*
(24) *Bottle Filler.*
(25) *Air Conditioners.*
(26) *Refrigerating Compressor.*
(27) *Cold Room Compressor.*
(28) *Chilled Water Tank.*
(29) *Feed Tank.*
(30) *Oil Fuel Tanks.*
(31) *Cochran Boiler.*
(32) *Water Softener.*

function will be to arrive at finalised plans, layout of plant, etc., and to prevent alterations being found necessary once the work of construction has commenced.

Much time and money can be lost by having to deal with " afterthoughts " which usually mean improvisation with consequent ill-effect upon the finished job, and possibly on the quality of the milk handled.

The Main Building. This will comprise the dairy and cold stores and usually the power house and refrigeration room. Separate buildings may sometimes be constructed to house workshops, garages, stores, canteens, offices, and the main laboratory.

The following points should now be examined:

(1) Is it intended that the dairy should be a ground floor building, or is plant to be erected on suspended floors?

(2) Is the building to be constructed of reinforced concrete or of brick?

(3) Is it intended to use the dairy for publicity purposes, and will organised parties be taken round to view the process carried out?

As these are among the essential considerations, it is well to examine them in some detail.

1. ***Nature of the building.*** There seems to be a distinct tendency to construct ground floor dairies (Anon. 1950), sometimes with offices and laboratories on a first floor. There may be a mezzanine floor for the storage tanks for treated milk. This floor need only be sufficiently high to enable treated milk to flow to the bottle filler bowls and can filling equipment by gravity.

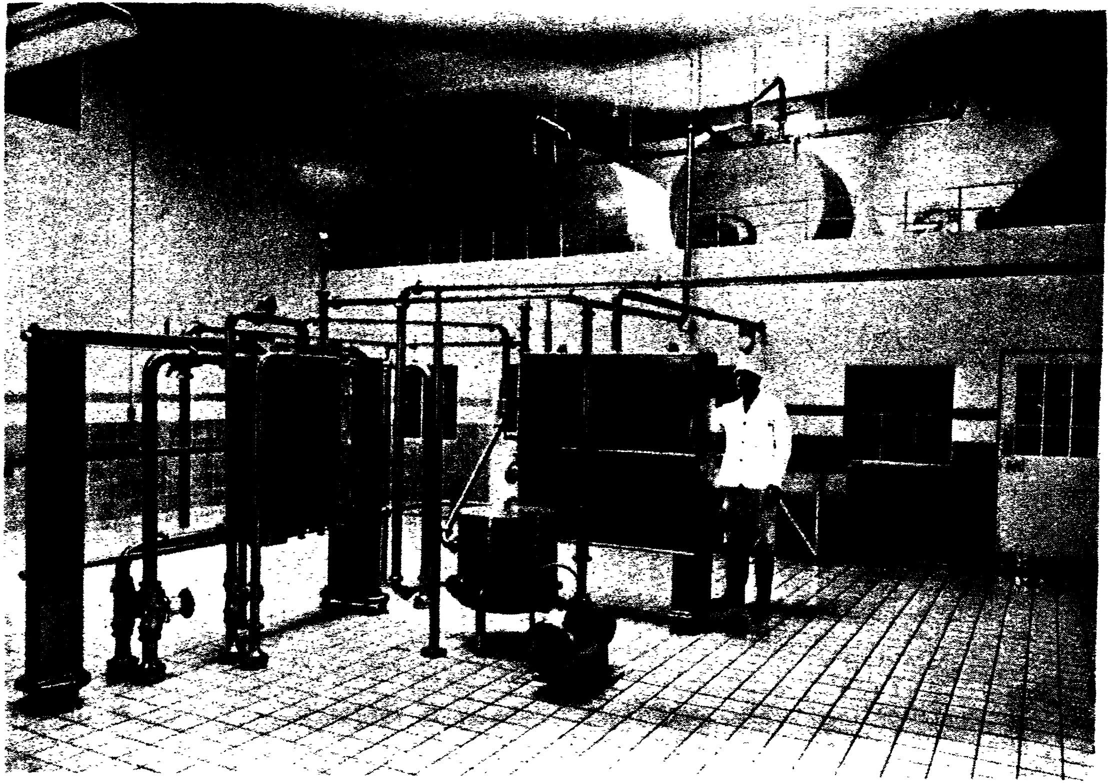
If the site allows, there appear to be advantages in a single floor arrangement of the plant. In such a building the foundations and footings would be lighter, and with the possible exception of a mezzanine floor, heavy steelwork would be unnecessary for any floor construction for offices, laboratories, etc. This saving of steel has been a matter of first importance during the last 12 years and seems likely to be a factor requiring very careful consideration for some time to come.

The advisability of erecting heavy plant on the ground floor for reasons other than the conservation of steel, is considered later. From a working cost point of view the ground floor type of plant layout is probably less costly to operate, and the building more economical to build and maintain. An example of the ground floor dairy (with the exception of the pasteurising plant and milk storage) is shown in Fig. DLD 1. Sufficient space has been reserved in this plant at least to double the output. A good example of the ground floor arrangement is shown in Fig. DLD 2. In this layout only the milk storage tanks are on a suspended floor, giving sufficient fall to the inlet of the filling machines. The tanks should be adjacent to the processing room (Fig. DLD 3).

2. ***Materials of buildings*** (Farrall 1949, Funding 1949, and Rosen 1949*a* and 1949*b*). If it is desired to build several floors and to house heavy plant on suspended floors it may be necessary to use reinforced concrete with trussed steel for the floor construction.

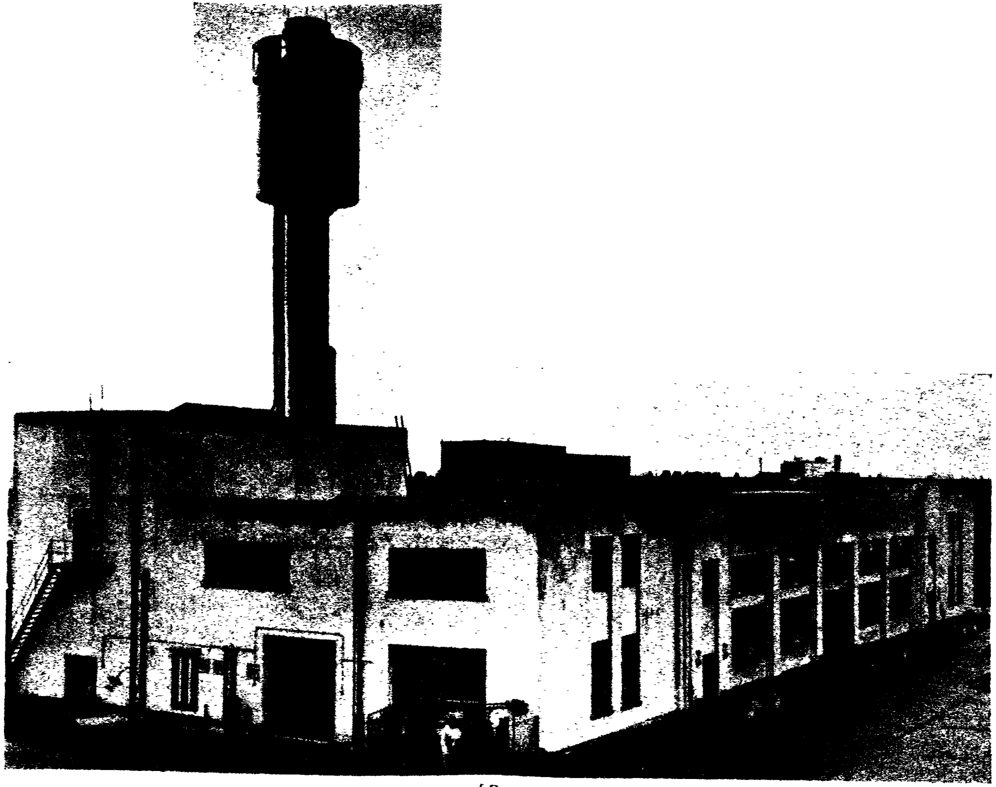
It is essential in planning a reinforced concrete structure absolutely to finalise the layout and positions of all pipe lines and services before commencing to build, as it is very often inadvisable to cut into walls and floors, etc., after construction. It is more difficult to make adequate provision for extensions to such a building, as the plans for the extensions would probably have to be completed at the same time as the drawings for the initial building. This might present some difficulty and would be likely to predetermine the type and even the make of plant to be installed later.

The finish to the exterior of a concrete building is often disappointing. Generally the finish consists of a thin rendering of some cement preparation, which in course of time cracks and gives a very dilapidated and neglected appearance to the building, and maintenance is likely to be heavy. An illustration of a dairy carried out in reinforced concrete is given in Fig. DLD 4.



[*By courtesy of Chichester Dairies Ltd.*

FIG. DLD 3.—*Tanks Adjacent to the Processing Room.*



[By courtesy of Royal Arsenal Co-operative Society Ltd.

FIG. DLD 4.—*Dairy in Reinforced Concrete.*

It may be decided to use brick for constructing the main building in conjunction with reinforced concrete or steel for the frame. A very pleasing appearance can be obtained by the proper choice of suitable brick, and the maintenance costs would probably be less than in the case of a concrete exterior, as few repairs to the surface would be required, and the need for periodical cement wash would not arise.

3. ***Publicity and the building.*** If it is intended to conduct organised parties round the plant, some consideration will have to be given to the route to be taken by the guides when planning the general arrangement of the plant. Special arrangements are necessary for the reception of guests, tea room, lecture room, etc. Extra attention should be given to the construction of stairs which should be of non-skid material, having easy risers and broad treads, and a central hand rail should be provided if the staircase is wide.

Good publicity may be obtained by having an attractive front exterior, and this may be carried out in faience (Fig. DLD 5). The dairy frontage illustrated is of cream material with modelled panels of the dairy maid trade mark in blue, and has a clean and pleasing appearance. A feature of this building when first erected in 1930, was the bottle filling plant in the front window. The maintenance of such a frontage is negligible, needing only a weekly wash down by means of a hosepipe.

Planning the General Arrangement. Having decided upon the gallonage desired, and the extent to which future output will be necessary, sufficient space in the appropriate place should be allotted for each operation. It is at this stage that provision for future increase must be made, and much may be done when planning the space reserved for each section, apart from plans for future extensions of the building. To give an example: suppose it is decided to install 2 × 1000 gal. per hr. (pint) bottle washers to meet the initial quantity required. By increasing the height and width of the bottle washing room by a few feet more than is actually required to house the 2 × 1000 gal. washers, it would be possible, at a future date, to instal 2 × 1500 gal. washers in place of the 1000 gal. machines without having to enlarge the room. This principle can be applied to some other units of plant such as compressors, fillers and cappers, and pasteurising plant, etc. It must be remembered that any large increase in capacity must be allowed for in other sections of the dairy such as dirty bottle space, despatch bank, and cold stores, etc. It will be an advantage at this stage to consider the main sections of the dairy in some detail.

Milk Reception and Storage. From the time of arrival the milk should at each stage go forward by the shortest route practicable to its final destination on the despatch bank. The ground floor dairy has the advantage of facilitating this practice, Fig. DLD 2 being a good example.

It may be necessary in a large dairy to make provision for the reception of milk in rail and road tankers, and churn milk direct from senders. The reception section should be arranged to allow milk received by any of these means to be fed to a common milk storage room. This room may be at a level sufficiently low to permit of gravity flow of the milk (Fig. DLD 6) or situated at bank level and the milk pumped to the storage tanks. If pre-cooling is practised, the storage tanks would probably be erected at bank level. The pre-cooling unit may be housed in a partitioned section of the storage room. Provision will probably need to be made for the reception and storage of milk of several designations, and extra tanks installed to segregate these grades. The churn tipping and weighing gear (if used) should be adjacent to the milk storage room and it is an advantage to install separate tipping for graded milks so that they can be handled simultaneously with ordinary milk. If separate pre-cooling and pasteurising plant is also installed it will be possible to maintain a flow of all grades of milk to the despatch bank, and so facilitate making up the loads for transport.

Can Washing and Filling. This section may be in line with the bottle washing and bottle filling and so simplify the run of treated milk line and service pipe lines. It may be an advantage to install a conveyor to by-pass the can fillers, and by this means deliver clean empty cans to a separate bank for collection by the hauliers (Fig. DLD 6).

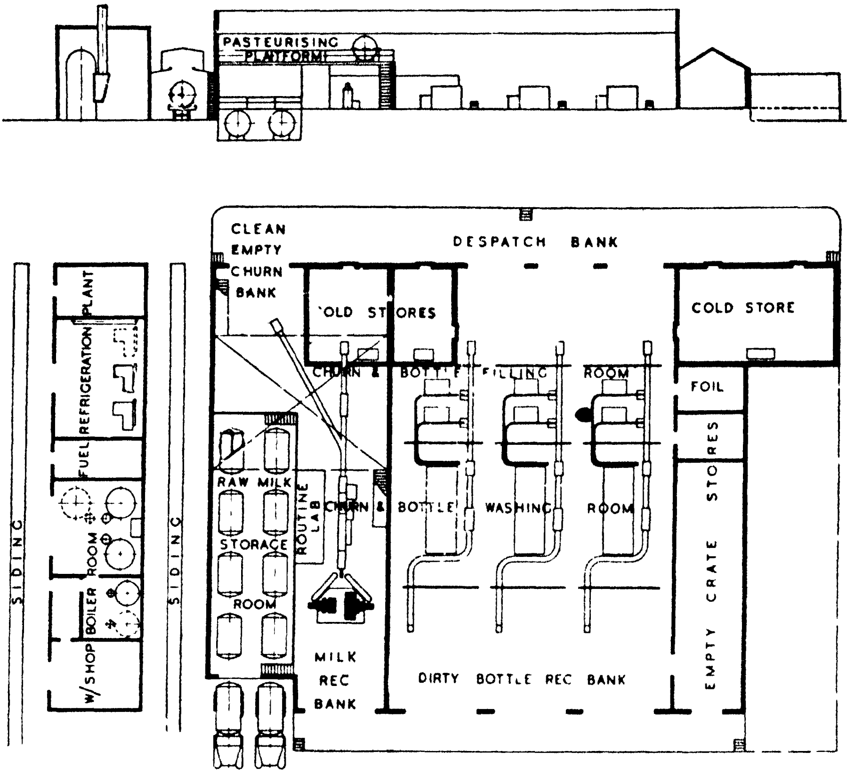


FIG. DLD 6.—*Typical Layout of Dairy for* 3000 5000 *gal. per hr.*

Bottle Washing Room. In the construction of this room, thought should be given to the space required for the desired number of washers with a blank or blanks for the installation of future machines. It may also be advisable so to space the washers to allow larger washers to be installed at a later date without having to extend the washing room walls. The roof construction of this room is important. The minimum of exposed steelwork in the roof should be used, and special construction is suggested. The washing units should be well spaced to permit the easy withdrawal of jet pipes and facilitate general cleaning. It must also be decided if crate washers are to be erected in the crate conveyor line. It may be desired to allow space for detergent filters or separators. If so, one filter or separator if situated between washers could probably service two machines. It must be settled how the washers are to be fed—whether by hand or by some mechanical feed device (Procter, 1948 and 1949). It is suggested that if the latter method is chosen, there should be provision to change quickly to hand feeding in case of breakdown or faulty operation of the mechanical device.

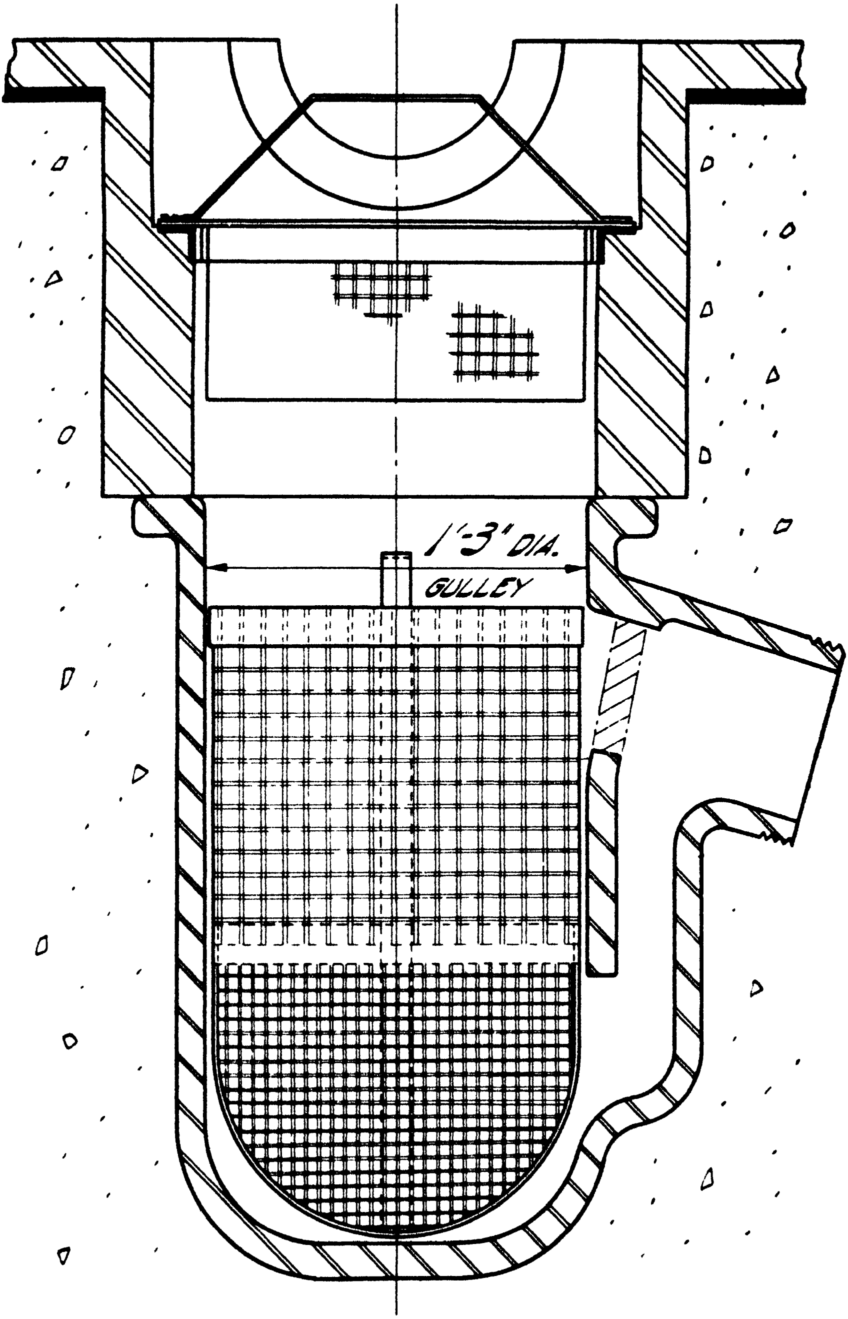


FIG. DLD 7.—*Assembly of Baskets in Gulley.*

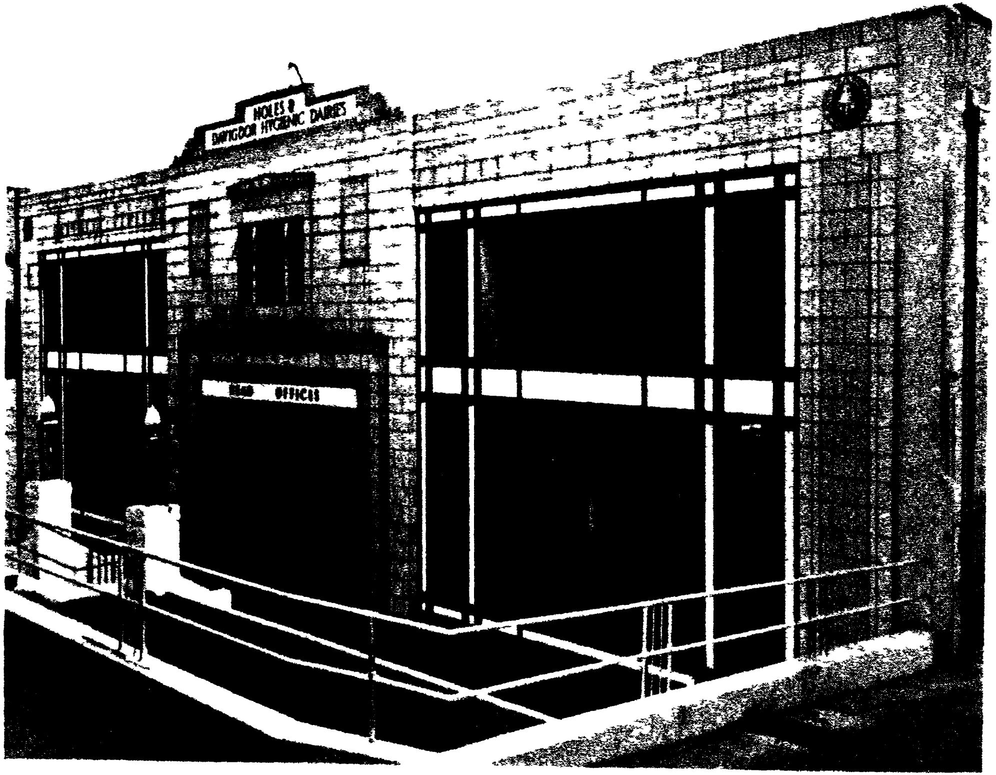
Adequate bank space for dirty bottles is essential in the rear of the washing room, from which draughts should be excluded as far as possible. The steam from each washer should be collected and disposed of.

The lighting and ventilation of this room are important. Artificial ventilation will probably be used, but care must be taken to minimise draughts. Good general lighting should be provided, with restful local lighting at the feeding and discharge ends of the washers.

The drainage of this room is also important. Sometimes a curb can be constructed round the washer, and the floor made with a good fall to one large gulley. Adequate precautions must be taken to collect all glass, discs or aluminium caps, and straws, etc. This may be done by the provision of specially constructed strong wire baskets seated over the gulley and flush with the top of the gulley, with a second basket in the gulley itself (Fig. DLD 7). If a curb is used it may be constructed of bull-nosed blue brick, as a concrete curb is likely to become chipped or broken. In some cases no curb is used, the washers being set on pads and allowed to drain to the floor. Usually a good fall should be allowed towards the feed end of the washers and an adequate number of gullies provided. Where a battery of washers is operating, glass, etc., may be distributed over the whole of the washing room floor, and difficulty may be experienced in keeping it moving to the channels and gullies. It seems preferable to concentrate the glass from each washer by means of a strong and properly constructed curb. The walkway between washers may be of cast iron grids in granolithic. Tiles are not recommended for any of the washing room floor, but a pressed blue brick may be suitable, provided that difficulties of jointing can be overcome.

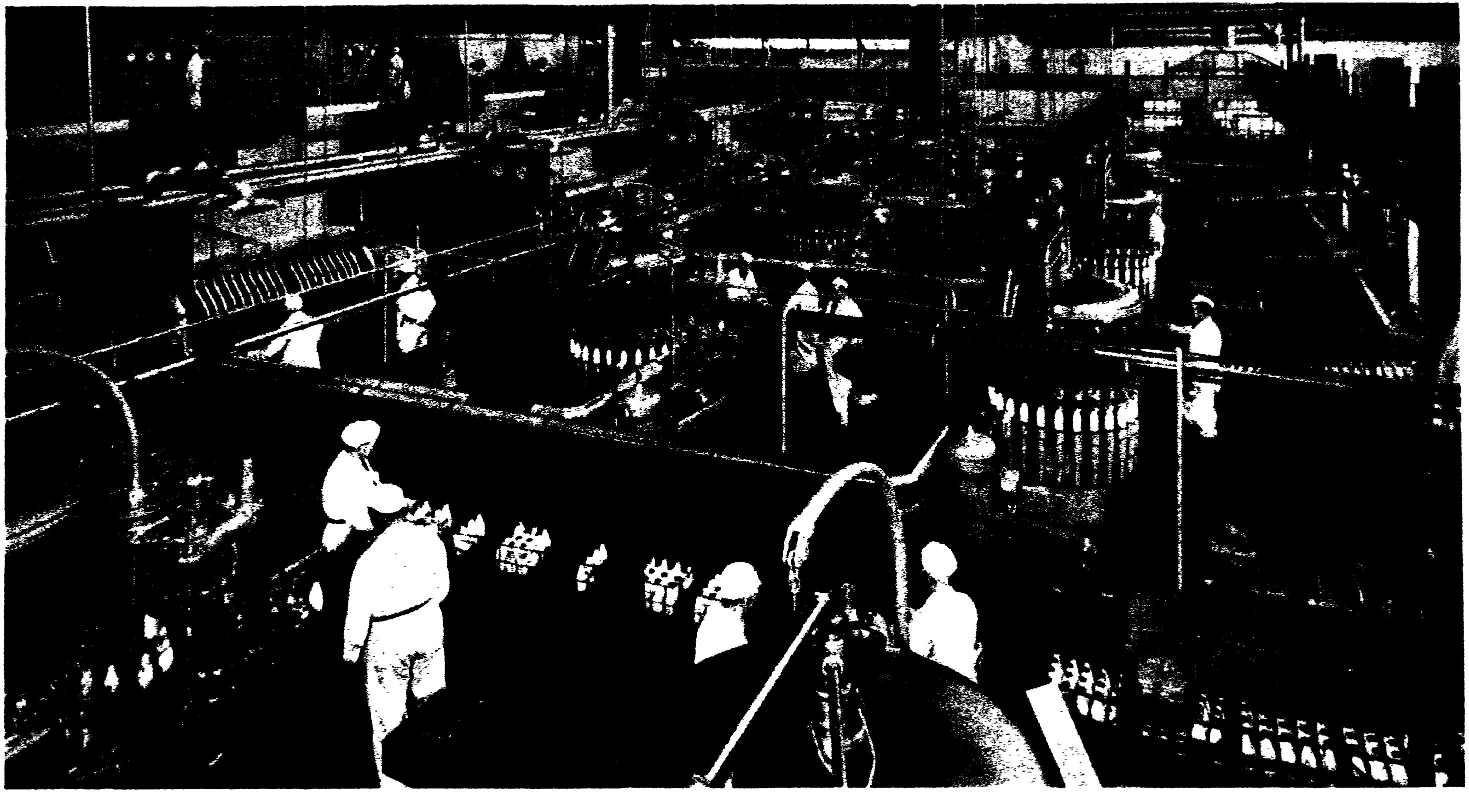
Bottle Filling and Capping Room. Probably the best arrangement for this room is the straight through layout, with the clean bottles entering through a wall or screen from the washers, passing round the fillers and cappers, and being delivered through the opposite wall for cold store or immediate despatch. A good fall to the floor terminating in half-round glazed or granolithic channels is very necessary. The floor is usually laid in tiles, but great care must be exercised in the choice of tiles or bricks and the material used for jointing, especially at that point where the floor marries with the channel. It is sometimes desired to keep the floor of the filling room wet, and to achieve this a water pipe having small holes on the underside can be fitted about 3 in. from the floor at the highest point. Perhaps a neater method is to construct a small glazed channel at the highest point of the floor into which water is fed to the bottom of the channel and allowed to well up and spread over the floor.

The bottle and crate conveyors in this room should have special consideration. They should be designed to ensure as long a span as possible between supports, and by this means minimise the number of legs. In the filling room, and indeed throughout the whole dairy, the floors should be kept as free as possible from obstructions. The bottle conveyor should have suitable removable covers from a point as near the washers as possible, continuing to the fillers (Fig. DLD 8). These covers should be shaped to prevent their being used as a resting place for tools, etc. The milk line (Anon., 1951) and other services, which will have been planned in the general arrangement and later in the working drawings, should if possible be suspended and not supported by means of pipe supports from the floor. As far as possible the filling room should be kept clear of conveyor driving gear. From the point of view of appearance it is well worth giving considerable thought to the pipe line services. These, other than the milk line, may be housed behind the screen or wall separating the filling room from the bottle washing room, and brought through only at those points necessary to service the plant. The general lighting should be good with local lighting in suitable positions over the machines.



[*By courtesy of Holes & Davigdor Hygienic Dairies Ltd*

FIG DLD 5—*An Attractive Front Exterior*



[By courtesy of Express Dairy Co. Ltd.

FIG. DLD 8.—*Bottle Conveyor and Fillers.*

Pasteurising Room. The arrangement of pasteurising plant is largely a matter of individual preference. Ample space should be allowed around each unit to facilitate operation and cleaning. The size and number of units installed will of course depend on the output desired and the provision to be made for handling various designations simultaneously. Milk pumps should carefully be considered and reduced to a minimum.

Cold Storage. It is often found, even in large dairies, that insufficient space has been allowed for cold stores, and it is of paramount importance that adequate provision should be made. Sometimes the cold store is so constructed that all the full crates are delivered into the store irrespective of whether the milk is to be stored or sent direct to distributing depots. This means that the loaders are required to work always in the cold store. The other procedure is to deliver the full crates directly to the loading bank for immediate dispatch to the distributing depots, and truck any balance required later to the cold store. If reference is made to Fig. DLD 6, it will be seen that the layout allows for the latter practice, and that on the dairy being extended by the removal of the temporary crate and foil stores, the two new units installed would deliver direct to the larger cold store, and as this would remain shut a more economical use of refrigeration would result.

Boiler and Engine Room. It is usual to arrange for separate rooms to house the boilers and refrigeration plant. This may not be necessary when oil-burning boilers are used, but if coal feeding is the method used for raising steam, it is preferable to install refrigeration plant, air compressors, pumps for water raising if a well is used, circulating pumps, etc., in a separate room.

Cleaning of Rail and Road Tankers. This very necessary function is often carried out under the worst possible conditions, and attempts are made to wash and clean the tankers in the open in all weathers. If possible, the siding should be enclosed so that the work can be performed under cover. It should be so arranged that the tanker can be approached from the top for cleaning to obviate the rather cumbersome method of keeping all the cleaning gear at ground level by the side of the track, which necessitates the cleaner climbing up each individual tanker. The proper cleaning of the road tankers presents less difficulty, as they can be taken to a washing room where one of the operations can be a thorough rinse by jet pipes of the outside of the tankers with soft water.

It is often very difficult properly to paint rail tankers. It is sometimes done in the open and the best results are not obtained. If possible a spur should be taken from the rail siding and a paint and repair shed provided on the spur so that tanks can be properly housed while being painted, etc.

Other Sections and Buildings. In addition to the several sections described many other subsidiary sections or departments will need to be provided, amongst which are: stores for detergent, salt, and consumable stores; stores for spare parts; stores for transport requirements, petrol and oil, etc.; engineers' stores and workshop; canteen, and changing and locker rooms; office accommodation; laboratory accommodation and stores; special temperature controlled store for aluminium strip; a crate and bottle store; fuel oil or coal storage; water softening room; garage and transport office; electrical switch room; first aid room; clothing store and issue department.

Special Considerations. ***Roof construction.*** It has been said that it is very desirable to keep exposed steel to a minimum in roof construction. This is especially so in the main dairy building for the following reasons:

(1) It is usually a forest of steel which is dirty and unsightly.

(2) This steel work requires frequent chipping and painting, with consequent high maintenance costs.

(3) Engineers tend to use this somewhat convenient structure as a starting point from which to hang various pipe lines and other apparatus, sometimes with little regard to the extra strain being put on the span trusses.

The alternative to the exposed steel roof is to follow the normal practice of erecting steel staunchions appropriately placed, which carry portal beams (Fig. DLD 9). These portal beams in turn carry the purlins which may be of wood or, preferably, steel channel. The staunchion, portal beams, and purlins are concrete cased, and if rendered in a smooth finish are, so far as experience of their use in dairy construction goes, better left unpainted. It will be noted that the purlins are arranged with the open side of the channel towards the apex of the roof, to allow of better nesting of the concrete surround.

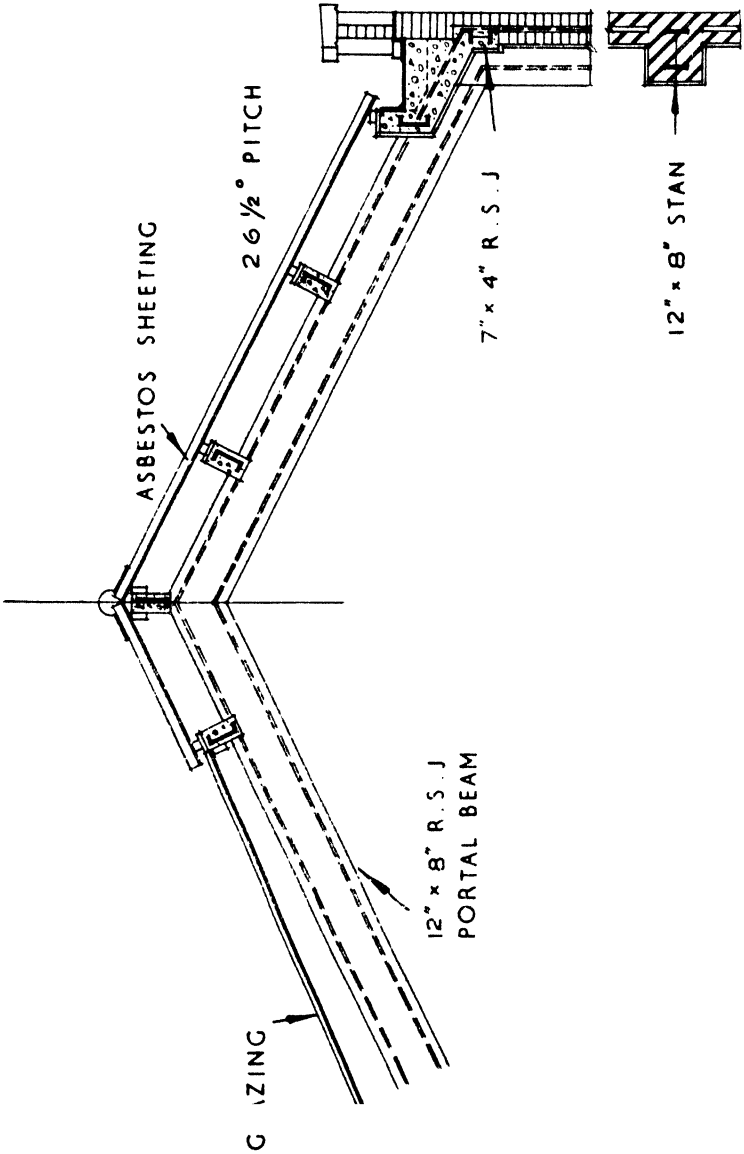


FIG. DLD 9.—*Roof Construction showing Portal Beam.*

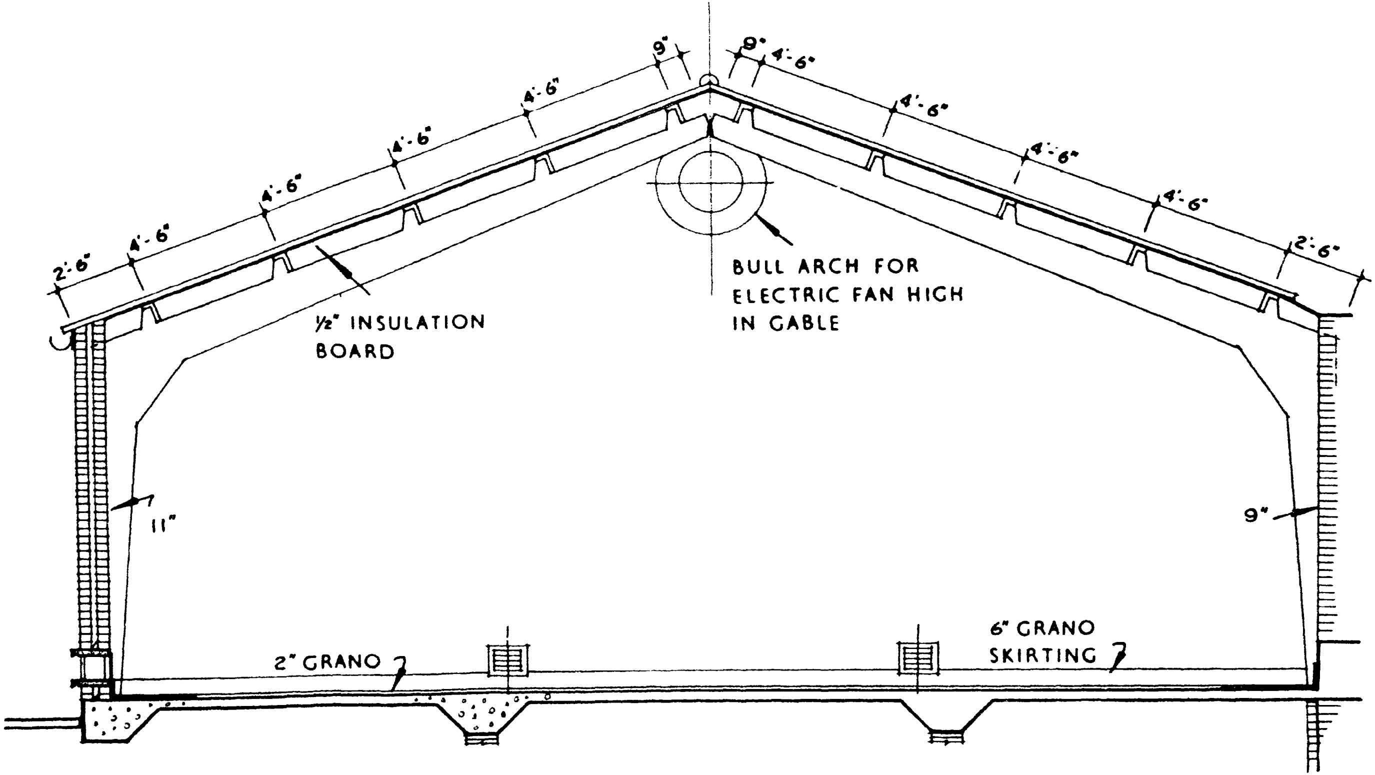


FIG. DLD 10.—*Roof Construction. Reinforced Concrete Frame.*

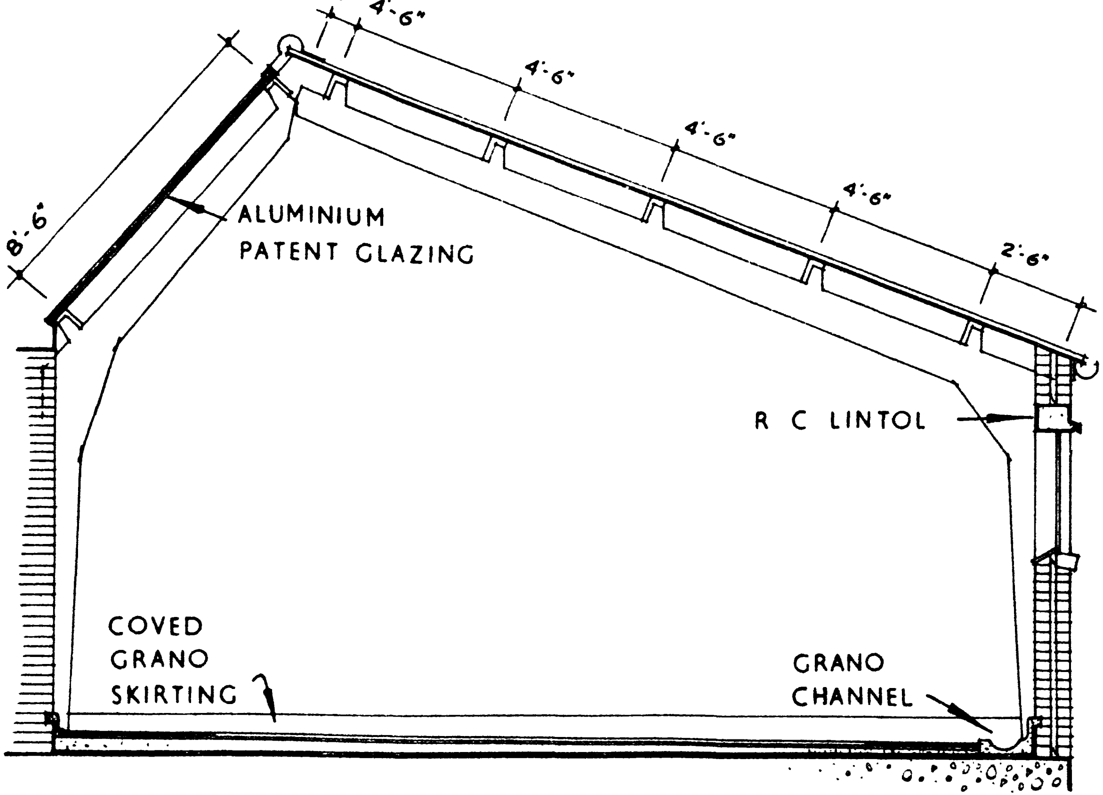


FIG. DLD 11.—*Roof Construction. Suitable Pre-cast Frame for a North Light.*

A second method is to pre-cast, usually on the site, the reinforced concrete frame (Fig. DLD 10). If a glazed north light is required a suitable pre-cast frame is shown in Fig. DLD 11.

Suspended floors. It is sometimes difficult to ensure that a suspended floor will, under all circumstances, remain leak proof. Sometimes batteries of heavy storage tanks, with their fluctuating weights according to whether they are full or empty, are housed on such a floor. Even if the floor is reinforced directly under each tank to take the weight, there will probably be deflection of the surrounding floor with resultant seepage of water and milk residue through the floor. The weight of steel required to construct such a floor is usually very considerable, and consideration should be given to this fact. The weight of 3000 gal. storage tanks full is about five times greater than when empty, and to construct a suspended floor capable of standing up to these severe conditions entails an outlay of steel and capital which can rarely be justified.

Suggested finish of interior walls of dairy. Tiles or glazed brick should be used throughout. Painted surfaces are not suitable for a dairy and require constant maintenance, the cost of which will probably soon outweigh any extra capital cost of providing a tiled or otherwise glazed finish. A further consideration in favour of tiling is that a maximum of reflected light can be obtained with a consequent saving of artificial light. Apart from the material used, it is recommended that all walls are coved at all junctions with other walls, floors or ceilings.

Glass bricks may be used to advantage where it is essential to have good natural light or when borrowed light is necessary.

Milk reception room. White glazed brick is suggested with Staffordshire blue brick to a height of, say, 5 ft. The base of these walls may receive rough usage with consequent damage to white glazed brick, if carried down to floor level.

Milk storage room. White tiles or glazed bricks are suitable with a skirting of about 15 in. of blue brick.

Can washing and can filling room. The finish described for the milk reception room is suggested.

Bottle washing room. This may be finished in white glazed brick with a skirting of about 15 in. Staffordshire blue brick.

Bottle filling and capping room. White tiles are suitable throughout with about 9 in. skirting of white glazed brick.

Pasteurising room. The same finish is suggested as for bottle filling and capping.

Cold store. Best quality white frost-proof tiles are recommended with a skirting of about 12 in. of blue brick. When constructing the cold store, adequate provision should be made for a strong and effective fender round the walls at the appropriate height.

Boiler room and engine room; Loading bank and dirty bottle bank walls. Blue brick to 4 ft., and finish in white glazed brick.

Suggested floor finishes (Harper, 1951*a* and 1951*b*). Cast iron grids set in best granolithic are recommended for can receiving bank, dirty bottle receiving bank, dispatch bank, empty can bank, and cold stores. The sections of the cast iron grids, which are usually square, should not exceed 1 in. clear. It may be advisable to have these floors laid by specialists in granolithic, as so much depends on the manner in which they are laid and the quality of the material used. If possible only one side, or at the most two sides, of each grid should be straight edged to facilitate a better knit floor with fewer metal to metal joins.

At points where traffic converges, such as cold store doors, a half-inch steel plate may be laid secured by countersunk bolts, and with serrated edges to marry up with the cast iron grids. The granolithic bed of any such plate must be dead level. Retaining hooks should be welded to the underside of the plate to key into the granolithic bed.

Filling and pasteurising rooms. Usually these floors are tiled, sometimes not with any great success. The tile used should be as thick as possible and very carefully laid on a properly prepared surface. The width of the jointing and the material used for jointing require much consideration.

Bottle washing room. This floor may be of granolithic with cast iron grids where necessary, or Staffordshire blue brick. Whatever the material used, this floor should have really adequate falls to channels and gullies.

Milk storage room. A good tile seems suitable for this floor with perhaps walkways between the tanks in blue brick.

Boiler room and engine room. The floors of these rooms can quite well be tiled throughout.

Laboratory. A good quality rubber laid on a wooden floor has been found to give satisfactory service, and is pleasant to work on.

Machine pads and bases. Often these are concrete pads tiled to match up with the flooring. This method of covering the pads is not always satisfactory as the tiles become loose and come way from the concrete. A lasting pad or base can be formed by using selected blue brick, bull-nosed where required. It is worth while taking special care with the jointing to give a neat and not unsightly job.

Wall decoration. A good effect can usually be obtained by introducing a little colour on the white background of tiles or glazed brick. A line of coloured tiles can be used some 5 ft. from floor level. This height may of course vary according to the height and size of the wall.

Window frames. These are usually a source of trouble and expense to keep painted. If metal frame types are used it may be possible to obtain them finished in vitreous enamel. The extra cost may be considered justified when set against the inconvenience and expense of the maintenance involved by scraping and painting the ordinary metal frames.

Interior window sills. Window sills may be tiled or of glazed brick or blue brick—whichever matches up to the surrounding finish. As they are usually a resting place for all sorts of odds and ends they should be constructed so that the interior sill is at an angle of about 45°. As a relief to a large expanse of white, sills can very well be carried out in colour to match the line of colour of the wall decoration.

When deciding upon the interior finishes of a dairy which it is intended to use for publicity purposes, it is well worth while to give some thought to a scheme of relief in colour.

General recommendations. The foregoing has dealt only in general terms with proposals and suggestions which may prove helpful to those entrusted with the task of co-ordinating the activities of all those specialists whose work goes to the creating of a modern dairy. There is a wealth of detail to be discussed and settled, and this must be done at the drawing board stage, and not departed from in any major respect, if the project is to be brought to a satisfactory conclusion.

The person chosen to be in charge of the work of planning the general arrangement of plant and buildings, and of watching the work proceed through all its stages to the finished job, will need to have specialised knowledge of a high order and be in a position to devote almost the whole of his time to the work. If he cannot give sufficient time to the project by reason of normal business calls upon his time, it may be well to engage the services of a consultant whose duties could quite properly be not only to advise on the initial layout and plans, but to pilot the job through and co-ordinate the work and progress of the working committee, and later all those various sections which carry out the decisions of the committee. By this means the project should go forward in a smooth manner with little delay owing to one section holding up the work of others. The consultant should bring an accumulated experience gained from a variety of jobs, and a knowledge acquired in a wide and varied field.

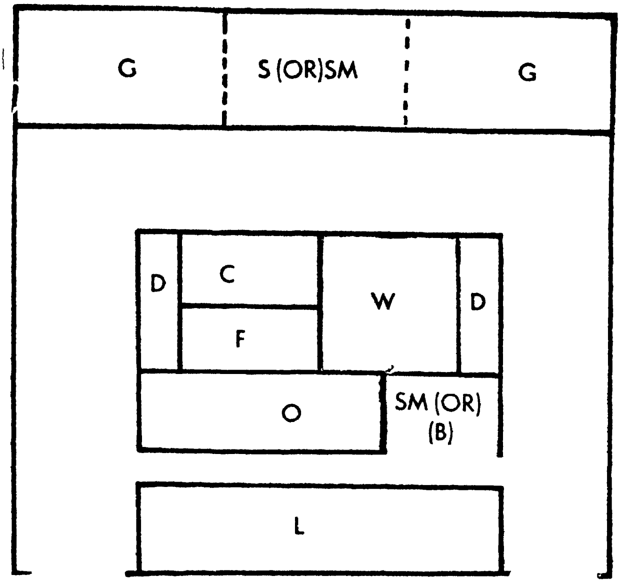


Fig 1

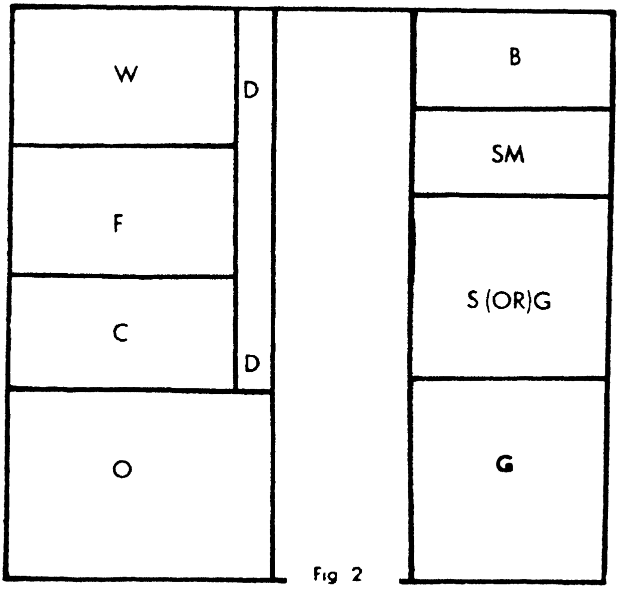


Fig 2

KEY

G	Garage	B	Boiler
S	Store	D	Dock
C	Cold Store	L	Garden
O	Offices	SM	Staff Room
W	Bottle Washing	F	Processing

FIGS DSD 1 and 2 *Designs for Small Dairies*

Refs.: Anon (1950), *DI*, **15**, 1040; Anon. (1951), *D*, **68**, 323; Dierickx (1949), *IDC*, **3**, 582; Farrall (1949*a*) *IDC*, **6**, 189; (1949*b*), *IDC*, **3**, 625; Funding (1949), *IDC*, **3**, 633; Harper (1951*a*), *JSDT*, **4**, 184; (1951*b*), *DI*, **16**, 1159; Horne (1949), *IDC*, **3**, 598; Matthews (1948), *JSDT*, **1**, 155; Procter (1948), *JSDT*, **1**, 136; (1949*a*), *IDC*, **4**, 145; (1949*b*), *IDC*, **6**, 230; Rosen (1949*a*), *IDC*, **3**, 638; (1949*b*), *IDC*, **6**, 199.

DAIRIES, SMALL, DESIGN OF. Many dairy buildings to-day do not conform to a regular plan or design, due to the fact that they have been thrown together without reference to a master plan or a thought for convenience or economic utility.

The rapid expansion of the dairy trade and developments in the methods of delivering milk have created the necessity for housing machinery and vehicles. Buildings have been given immediate weather-proof cover irrespective of design. Entirely new buildings erected in recent years have shown a new trend in dairy design. The grossly ornamented designs of the past have given place to straightforward buildings of simple lines which are nevertheless pleasing to the eye.

The basic requirements of dairy buildings are immediate utility with adaptability for future requirements. Buildings are required to house equipment for processing, bottling, and storing milk, together with accommodation for transport vehicles, dairy operatives and administrative staff.

There are several factors which govern the choice of site and shape of building. One of the most important of these factors is the question of whether to take bulk or ex-farm milk into town or urban areas, and then process and distribute in bottles on the spot, or whether to process and bottle in the country and carry the bottled milk into the town or urban areas. This gives rise to choice between two plans, although available capital may decide the issue.

In the country where land and facilities are relatively cheap, the dairy can be constructed as a single storey square type of building with a traffic way on each side (Fig. DSD 1). This type, if well laid out, can be a sound economic unit, while well-kept grounds and gardens will give enhanced beauty to a plain simple structure, at the same time giving an impression of order and cleanliness which can be of great publicity value.

The town dairy may have to be more compact (Fig. DSD 2). Buildings arranged on two or three sides of a central yard makes for an economic unit. It may be necessary to use two-storey buildings because of the limited floor space.

The site itself may influence the general design. Rising ground can be utilised to give different loading levels, while adjacent tall buildings may dictate the type of structure especially with reference to lighting, ventilation and siting of boiler chimney.

Again one has seen dairies erected on cheap, wet, or rough-filled land which have required raft construction. Dairy floors have to stand vibration and weight of machines, etc., and unless the floors have a solid foundation they are liable to crack and give rise to drainage difficulties if not to polution of water supplies through seepage.

The choice of site may be dictated by the presence or absence of suitable water supply in country districts. In town it is usually possible to draw water froma public supply, but it is often cheaper to draw water from a boring on the premises. In such cases provision will have to be made for water storage tanks. Sewage disposal is often a problem and may decide the siting, since the main outlet should be at the lowest point and it may be necessary to re-arrange the plans to meet this.

The average dairy is dependent on electric power supply, and if a satisfactory public supply is not available, accommodation may have to be provided for electric generator plant.

The requirements of local authorities must be met with regard to designated milks. There are, however, certain fundamental principles to observe in designing buildings for the reception, processing, bottling, and storage of milk for dispatch to consumers. The dairy designer should endeavour to provide separate compartments for each process. The departments should be arranged so as to provide a smooth flow through the dairy of both milk and bottles. Milk should enter at one point and leave in bottles at another, while dirty bottles received at one point should move gradually through the washing and filling department to the cold store, where they remain until dispatch. By following this system, bottles and milk can be handled economically and at the same time, contamination of milk and plant is kept to a minimum. Working space floors at lorry height tend to give speedier handling of milk in and out of the dairy. The provision of mechanical conveyors and other aids in order to cut down the amount of labour is an important factor to be considered in dairy design. The actual size and shape of the dairy must be governed to a large extent by the equipment used.

The producer-retailer or smaller retailer will normally use hand-operated equipment for bottle washing and filling, while large retailers must make full use of mechanical aids. For the producer-retailer the system usually operated is as follows: Bottles returned from the rounds are soaked and washed on the usual power-operated rotating brush washers. The bottles are then rinsed in a tank or on jets of clean water. The bottles in their crates are then steam sterilised in a steam cabinet. The bottles are allowed to cool overnight in a clean storage space. Milk of designated grade (*i.e.* Tuberculin Tested milk) is often bottled from the cooler tray as it is cooled direct from the cow. The bottled milk is then cold-stored until required for dispatch. The equipment for the producer-retailer would consist of bottle-soaking tank, bottle-washing machine, rinsing jets or tank, steam cabinet, water tube steam boiler and cold storage cabinet with milk cooler attached. One or two points in the layout of equipment should be noted. The boiler should be in a separate compartment with fuel store near by. The boiler should be near to the steam cabinet and washing troughs. The cold store may be operated on the direct refrigeration system with one compressor unit for the storage and one for the milk cooler. The indirect refrigeration system, using brine for cooling may be used, but the difficulties encountered with a brine installation are numerous. It is essential to fix the refrigeration units in a cool airy place, otherwise difficulty may be experienced in hot weather just when it is wanted most. Many units become oily in use, and this is undesirable in the dairy, while condensation from dairy steam is not good for electrical installations. Therefore, it is best to keep the refrigeration unit out of the dairy proper.

Condensation which occurs in cold stores is destructive to flooring and woodwork. Therefore, the floor should be well drained, otherwise water may penetrate the cork or other insulation and ruin it.

Steam for sterilisation and water heating may be provided by a boiler using coal, coke, or oil as the heating medium. Near towns gas and electricity may also be used, although they may prove too uncertain for an industry requiring attention 7 days per week.

The retailer buying raw milk from farms will be required to pasteurise the milk unless it is Tuberculin Tested. For the small retailer the batch system of pasteurisation is perhaps the only method available. In this system, milk is heated to 145° F. and held at that temperature for 30 min. usually in the same vessel, and then the milk is cooled and bottled. The large retailer dealing with over 500 gal. per day will find that the H.T.S.T. system of pasteurisation will be more economical since this equipment, with automatic bottle-washing, filling and capping machines, gives a speedy handling of milk.

The choice between hand and power machinery will depend on the type of labour available, since the success of hand operations depends on the personnel and the success of machine operations depend on maintenance, servicing and control by the management. To a great extent, the larger the dairy the more mechanisation is necessary in order to make an economic unit. Given a throughput of 1200-1500 gal. per day, it is possible to mechanise most operations such as bottle-washing, filling, capping and steam generation.

Storage facilities for detergents, cleaners, brushes, spare parts, etc., should be provided away from steamy conditions. Storage for cloths, filter media, bottle caps, drinking straws, etc., must be airy, dry and free from dust. Such accommodation can often be provided near to office quarters.

The offices and accommodation for operatives should be provided away from the noise and vibration of the dairy processing departments, such as churn washing, bottle handling, etc. The dairy staff should have ample mess-room facilities (even a canteen) with drying accommodation for wet clothing. Adequate washing facilities are also essential in the modern dairy, to encourage order and cleanliness.

The siting of the boiler house in relation to the other buildings is important. In order to get rid of as many fumes and soot as possible, the boiler chimney should be high enough to give good draught and should be sited in the direction of the prevailing winds, away from the main dairy, although it is essential to keep the length of steam piping down to reasonable proportions. In some situations it is essential to use coke as fuel in order to keep down the smoke nuisance which often arises with small boilers.

The owner must give guidance to his architect on many points with regard to the structure of the buildings themselves.

Many types of flooring materials are available, including asphalt which is fairly reliable and can be strengthened with iron reinforcing grids where wear is heavy. The asphalt floors will not stand treatment with hot water, and all hot water from drains and overflows should be piped clear of the floor. Concrete in various forms makes a good floor. It must be laid properly to give service and may be reinforced where the traffic is heaviest. Concrete is not so easy to repair as asphalt when wear takes place in small patches. Several forms of iron and composition tiles are available for flooring and give good service when laid properly in the right location. The architect should note that dairy floors require a steeper slope towards the drain than floors in other types of buildings, since milk standing on a floor gives rise to lactic acid which is destructive over a long period of contact. The walls of the dairy may be of different materials —brick, precast blocks or concrete cast *in situ* within a steel framed building. Open porous materials like foamed slag are not desirable since they are likely to absorb milk splashes. The walls should be constructed and treated to prevent condensation. All walls should be finished smooth inside with either glazed tiles or otherwise rendered smooth for 5 to 6 ft. from the floor. Processing rooms should not be too high, while low rooms give rise to draught—10 to 12 ft. is a suitable height. The use of sliding doors will economise space in small dairies. Swing doors should be spring loaded and wide enough for the traffic using them.

The window area must be as large as practicable and hopper windows may provide ventilation for the building. The ventilation must be adequate at all times with forced ventilation for use during spells of hot weather.

The provision of adequate lighting is essential and artificial lighting must be provided where necessary. Saw-toothed type of roofing can be used to give extra lighting in the dairy. Roof lights should face north in order to get even light and in order to avoid the direct rays of the sun, especially in summer time. The roofing material may be asbestos tiles or sheets or traditional slates. Corrugated iron roofing is not desirable since in summer time heat is transmitted to the dairy. The interior of the roof should be clear with few rods, struts or beams to collect dust. The whole roof must be capable of easy access for cleaning, and should be lined if there are many ledges to collect dust.

The traffic space around the dairy should be concrete faced and so laid that it can be washed easily. Provision should be made for vehicle cleaning. This can be done most conveniently on a patch of the traffic way which has been specially constructed and drained.

Accommodation for the manufacture of ice cream as a side line may have to be provided within the dairy structure. Such departments should be quite separate from the milk-handling rooms.

The aims of the architect should be to provide a building with ample space for machines and dairy staff, with adequate ventilation and lighting, with a fabric structure that is easily cleaned. The design should be simple, clean and bright and with an orderly layout.

See also Dairies, large, design of; Dairy farm buildings ; Electrical equipment; Management; Refrigeration equipment; Retail; Steam raising; Transport.

DAIRY. This word is the modern form of *deierie* (Middle English) which is derived from *dey*, a female servant.

DAIRY FARM BUILDINGS, DESIGN AND CONSTRUCTION OF. General provisions relating to farm buildings and water supply are contained in the Milk and Dairies Regulations of 1949. Precise constructional details are not prescribed therein, but the buildings must meet with the approval of the Milk Production Committee of the County Agricultural Executive Committee. The Ministry of Agriculture issue a series of leaflets dealing in detail with the planning and construction of cowhouses, milking parlours and farm dairies (see Refs.) and the design and type of construction described therein will normally meet the requirements of the Regulations, but prior consultation with the County Milk Production Officer is advisable in all cases.

I. Choice of Building Site. Consideration should be given to the following matters:

(1) Adequacy and quality of the water supply.

(2) Site and configuration—depressions and low-lying ground should be avoided as should also exposed sites.

(3) Convenience of access to the main pastures for livestock and to the main road for collection of milk and delivery of feeding stuffs.

Often the choice of site is governed by the presence of existing farm buildings, and in such cases it is very desirable to have prepared a complete plan of the existing buildings on to which the new buildings layout can be drawn. The whole farmstead layout can then be studied and proper consideration given to convenience of circulation throughout the buildings in carrying out normal farm routine labour operations.

II. Design. Accommodation for cows. The main considerations should always be (*a*) comfort and health of the animals; (*b*) economic use of labour in milking, feeding, cleaning down, dung removal, and general routine work; (*c*) hygienic conditions for milk production.

(1) *The cowshed, shippon or byre* (in which cows may be both tied and milked). For herds greater than some 12 to 14 in numbers, a double row layout with the cows facing outwards provides the most economical arrangement both in cost of building and for the labour requirements in normal routine operations. The inclusion of feeding passages is not essential and is a matter for individual taste.

The dimensions of the normal cowsheds are indicated in Figs. DF 1 and 2. The length of standing and manger will vary according to breed and size of cow, and also according to the method of tying the cow (Fig. DF 3). Close tying methods such as the yoke or Dutch tie restrict the movement of the cow lengthwise on the stall, and the latter can therefore be slightly shorter than is desirable with the other methods of tying. It is sound practice to vary the length of the standing uniformally throughout the building to provide for variations in sizes of the animals, and for the same reason ties should also be capable of slight adjustment in position.

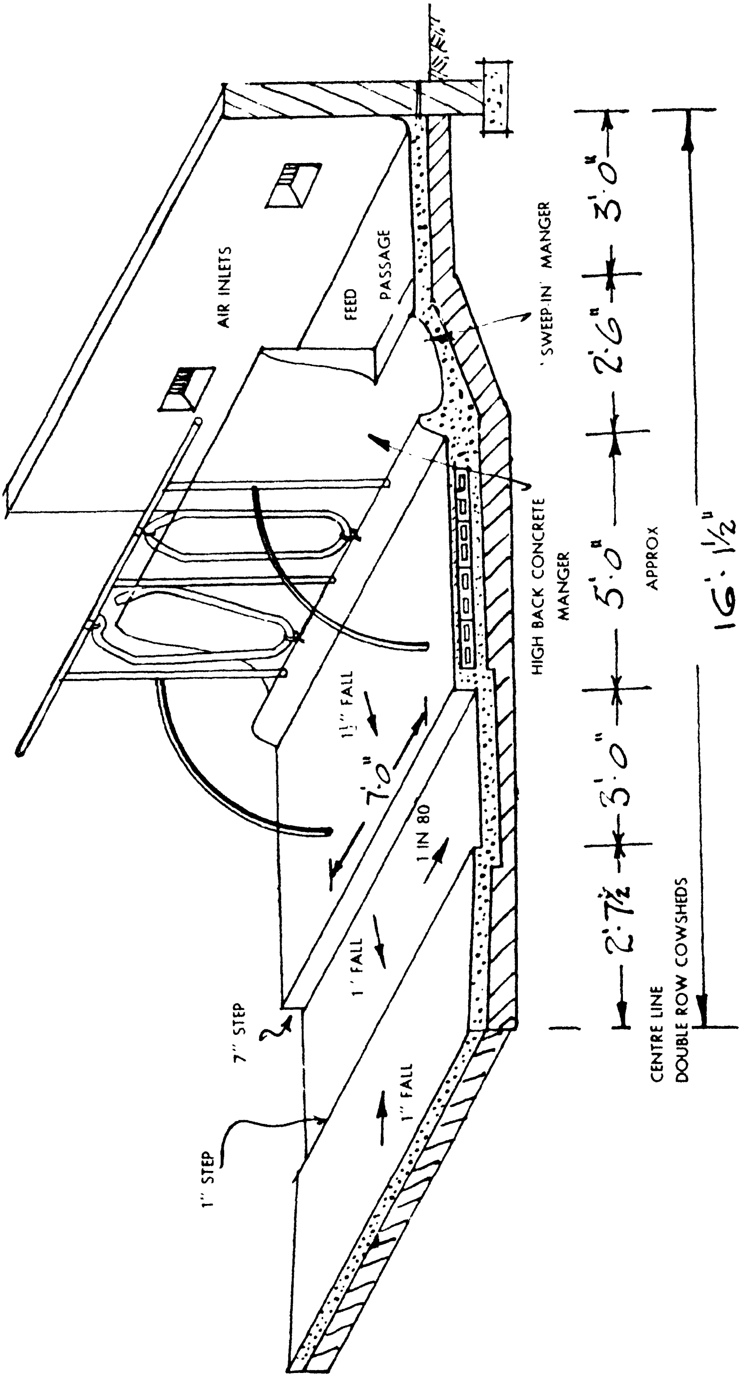


FIG. DF 1.—*Cowshed Construction.*

Stall divisions should be either of open tubular steel construction or of solid smooth surfaced concrete. Double stalls are usually provided, but single stalls will reduce the risk of a cow causing injury to another.

Mangers are usually formed either of concrete—preferably with a salt glazed lining—or of separate glazed troughs. In the case of the former, the division can be made removable in sheet metal hinged to the stall divisions so that cleaning down can be done in one continuous operation from one end of the shed to the other. A development of recent years has been the complete elimination of the manger except for possibly a depression in the floor or the provision of a small front curb.

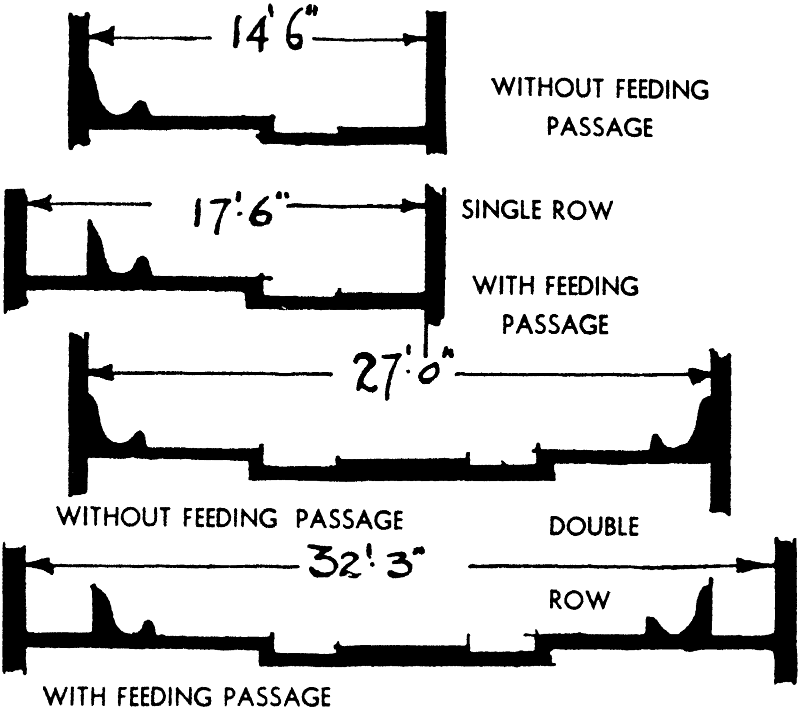


FIG. DF 2.—*Cross-sections of Floor. Alternative Cowshed Widths.*

The Americans use this system with a slightly raised feeding passage to form the so-called " sweep-in " manger.

The surface of all parts of the cowshed floor must slope towards a channel placed at the back of the standing. A certain divergence of opinion exists over the dimensions of this gutter, but a width of 2 ft. 3 in. is usually considered a minimum. There are definite advantages, however, in increasing this width up to 3 ft. or more, to reduce the possibility of a blockage. There should be a slight step of about 1 in. from the milking passage into the gutter, and a rise from the gutter to the standing of about 7 in. The channel should slope to a gradient of 1 in 80 to one or more outlets in the external wall where it should discharge into a gulley trap placed outside the building. The possible use of manure conveyors or other mechanical means for cleaning the dung channel is receiving greater attention nowadays.

Concrete is the material normally used for the passages and channel and frequently also for the standing. In the latter case, the drawback of it being a rather "cold" flooring may be mitigated by the formation of an air space below the surface. One cheap method of accomplishing this is to lay land drain-pipes on a concrete bed 2½ in. thick and then to cover the pipes with a further 1½ in. layer of fine concrete. The surface of the concrete should not be trowelled to a smooth finish owing to the risk of it proving slippery when wet.

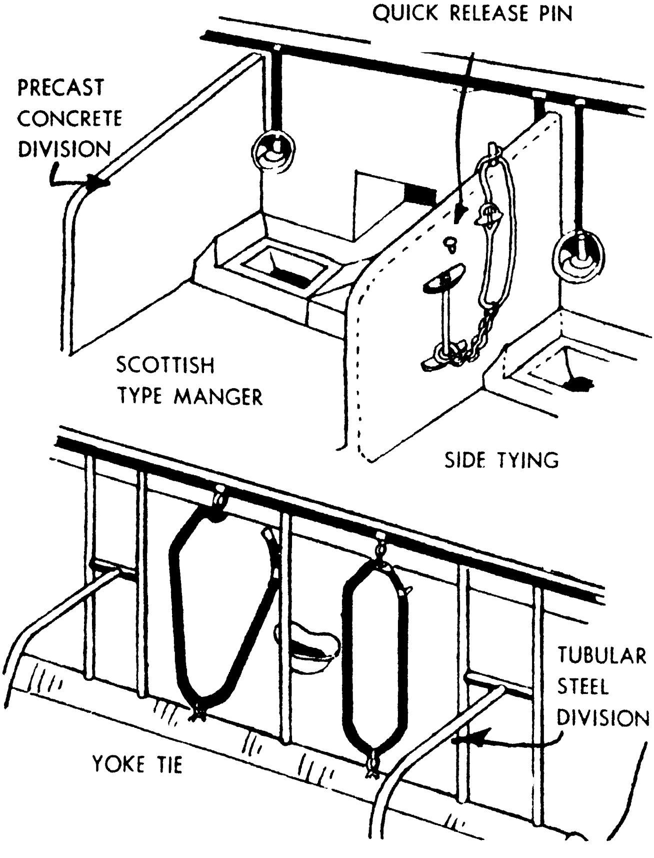


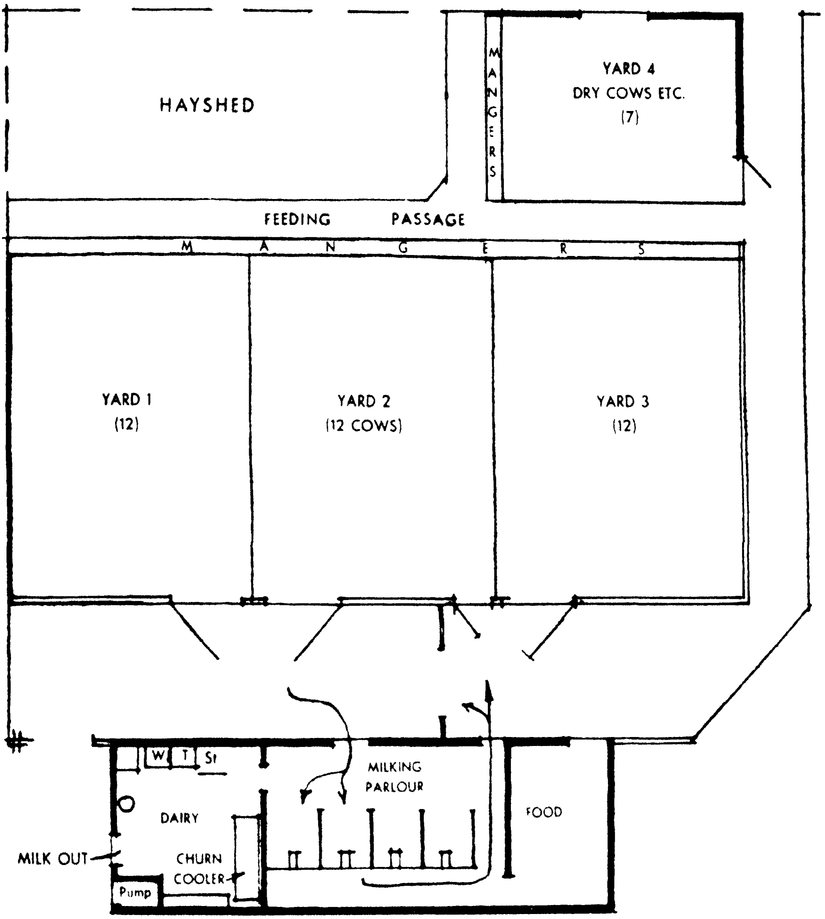
FIG. DF 3.—*Method of Tying.*

Roughening the surface by brushing with a stiff broom before the concrete hardens will give a more suitable finish. A hard wearing surface is, of course, essential, and due attention should therefore be paid to the choice of materials and to the mixing and laying of the concrete.

An impervious and easily cleaned surface is equally desirable for the walls, and so the application of a ¾-in. layer of cement and sand rendering (1 to 1 or 1 to 2) smooth trowelled on the face of brick or stone walls to a height of at least 5 ft. has definite advantages.

(2) *Yard housing.* The accommodation of cows in either partially covered or entirely covered yards and transferring them to a separate shed for milking

is a comparatively recent development. The essential requirement is an ample supply of straw estimated at 16 to 20 lb. per head per day. The advantages of the system are the greater freedom and comfort for the cows, the elimination of the daily mucking out of the cowshed, the simplification of drainage and water supply arrangements, and the production of good quality manure.



[*By courtesy of N.I.R.D.*

FIG. DF 4.—*Covered Cowyards at the National Institute for Research in Dairying.*

The problem of " bullying " by master cows can be eliminated by dehorning and by subdivision of the yard into sections each holding not more than 12 cows, and possible difficulties in rationing are overcome by the use of yoke ties over the feeding troughs either operated individually or in groups of 6 or more. Yokes automatically secured by the cow are becoming available.

Experience shows that the success or failure of this system depends to a large extent upon the arrangement of the yards in relation to the milking parlour. The route followed by the cows at milking times should be as short and as straight as possible and the possibility of cows on their way to the milking parlour becoming mixed with those returning to the yards must be eliminated. The normal

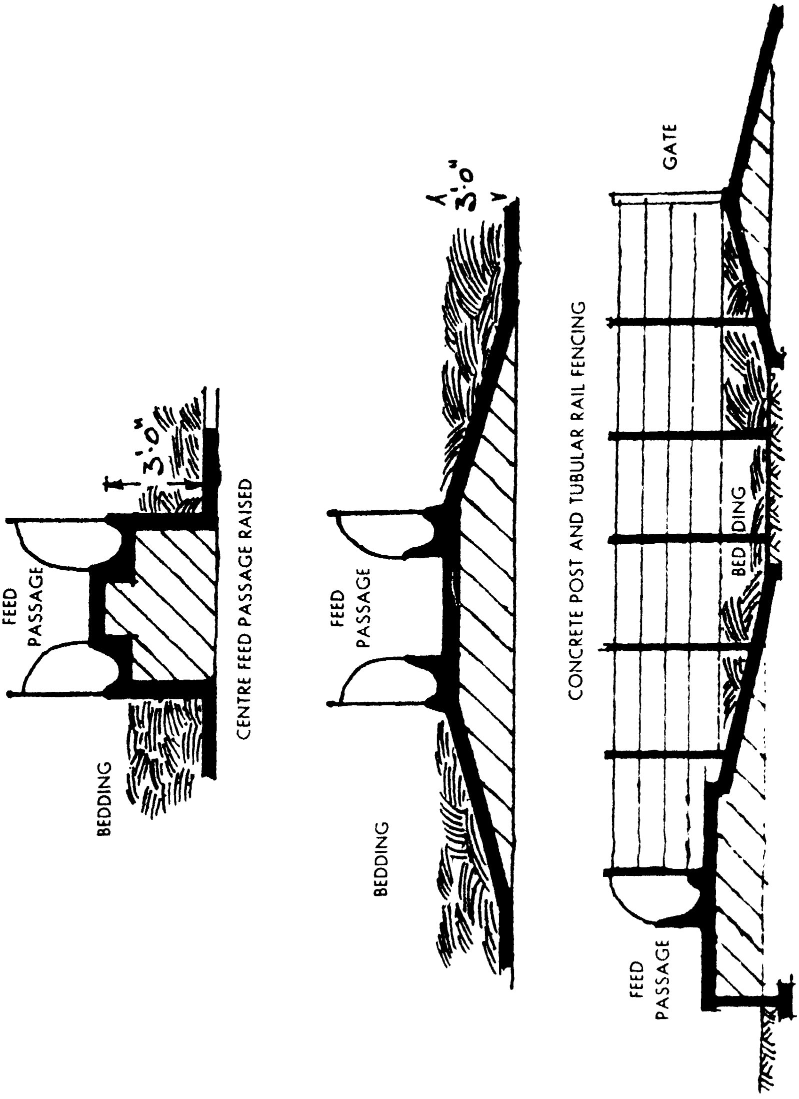


FIG. DF 5.—*Alternative Arrangement at Feeding Passage of Covered Yards. Section of Yard.*

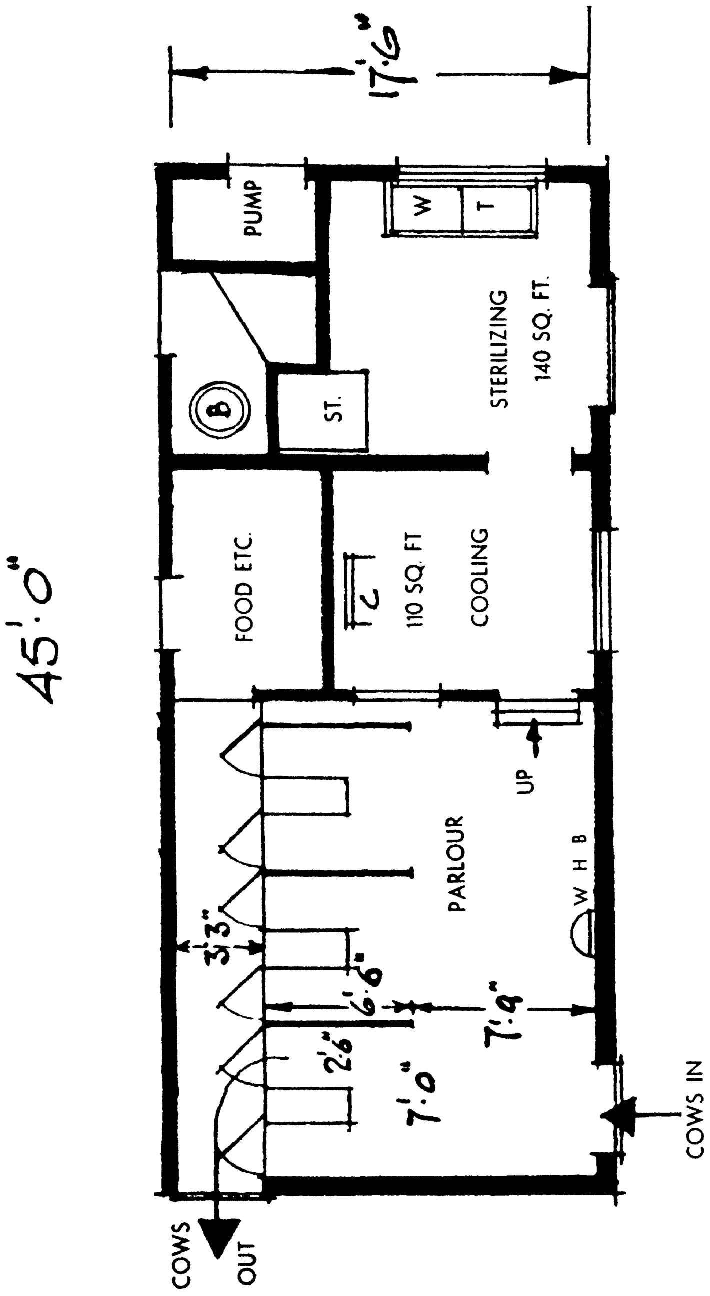


FIG. DF 6.—*Line Abreast " walk through " type Milking Parlour with Dairy Adjoining.*

yard space allowance is from 90 to 125 ft. per animal, with an allowance of manger space of between 2 ft. 6 in. to 2 ft. 9 in. Attention must also be given, as in the design of cowsheds, to convenience of feeding arrangements, removal of dung (preferably by use of manure loaders) and the introduction of bedding. A convenient arrangement used at the National Institute for Research in Dairying is shown in Fig. DF 4.

Geographical and climatic conditions determine the type of structure necessary, but shelter on the north and north-east sides is usually desirable. The surface of yards need not be concreted provided there is a well-drained and solid bottom. Allowance for the accumulation of bedding to a depth of some 3 ft. is necessary and mangers, fencing, gates and water troughs must be designed accordingly.

Alternative cross-sections of a yard are indicated in Fig. DF 5.

(3) *Milking sheds or parlours.* There are two normal arrangements: (*a*) with the stalls in line abreast, where there are usually 2 stalls per milking machine unit (Fig. DF 6 and Fig. MM 8 between pp. 746 and 747), and (*b*) the " Tandem " layout with the stalls in line ahead, with 1 stall per unit (Fig. DF 7).

Each of these arrangements may be of the single-level or of the two-level type in which the cows stand on a raised stall some 18 in. to 30 in. above the operator's floor level so that bending and stooping by the operator is eliminated. The single line tandem arrangement is particularly suited for installation in a narrow building of as little as 10 ft. 6 in. width. In the case of the line abreast layout, a building with a width of 17 ft. to 18 ft. is necessary, but for an existing building where all other considerations are satisfied, an absolute minimum of 16 ft. may be accepted in exceptional circumstances. The length of the building depends upon the number of units to be installed. In the case of the abreast layout, 7 ft. for each unit is allowed with a 1 ft. 6 in. or 2 ft. slipway at the end distant from the exit door (to give the cowman access to the front passage). Where the " in-line " plant is installed, 8 ft. is allowed for each unit. For a building with a ridge roof, a height of 8 ft. to the eaves is satisfactory. In some cases a loft is extended over the milking parlour thus enabling the food hoppers in the milking parlour to be filled from the loft where the concentrates are stored, with minimum effort and dustless conditions in the parlour. The height of the parlour in this case should preferably be not less than 8 ft. 6 in. The stalls are formed of tubular steel and the fronts are usually hinged so that the cows can walk through and out of the building after milking.

Feeding troughs are provided either fixed to the gate at the front of the stall or placed at the side near the front. In the line-abreast arrangement, where there are usually 2 stalls per milking machine unit, one cow can be prepared whilst the other is being milked, so that the milking machine is kept in practically continuous use. In the " Tandem " layout, in which there is only one milking stall per unit, separate washing stalls are sometimes provided. It is general practice to allow one milking machine unit for every 15 cows and to assume that one man can deal most conveniently with 2 units in the abreast layout and with 3 units in the " tandem " layout (plus in this latter case one assistant preparing the cows in the washing stalls). Special attention should be given to hygiene and in particular all floor and wall surfaces should be non-absorbent and easily cleaned and the roof lined to provide a flush surface. Floor channels are usually eliminated and the surface given a uniform fall to the external wall.

The approach to and exit from the milking shed should be concrete paved and drained and kept free from straw and dung, and where assembly yards are necessary an allowance of 30 sq. ft. per animal is desirable. A wash-hand basin or sink should be provided in the parlour and a stand pipe and hose for washing down.

(4) *Farm dairy.* The location of the farm dairy relative to the cowshed has an important effect upon labour economy in milk production. Although direct access from cowshed to cooling room, except via a ventilated lobby, is not desirable the dairy should be placed very close to the cowshed and in a

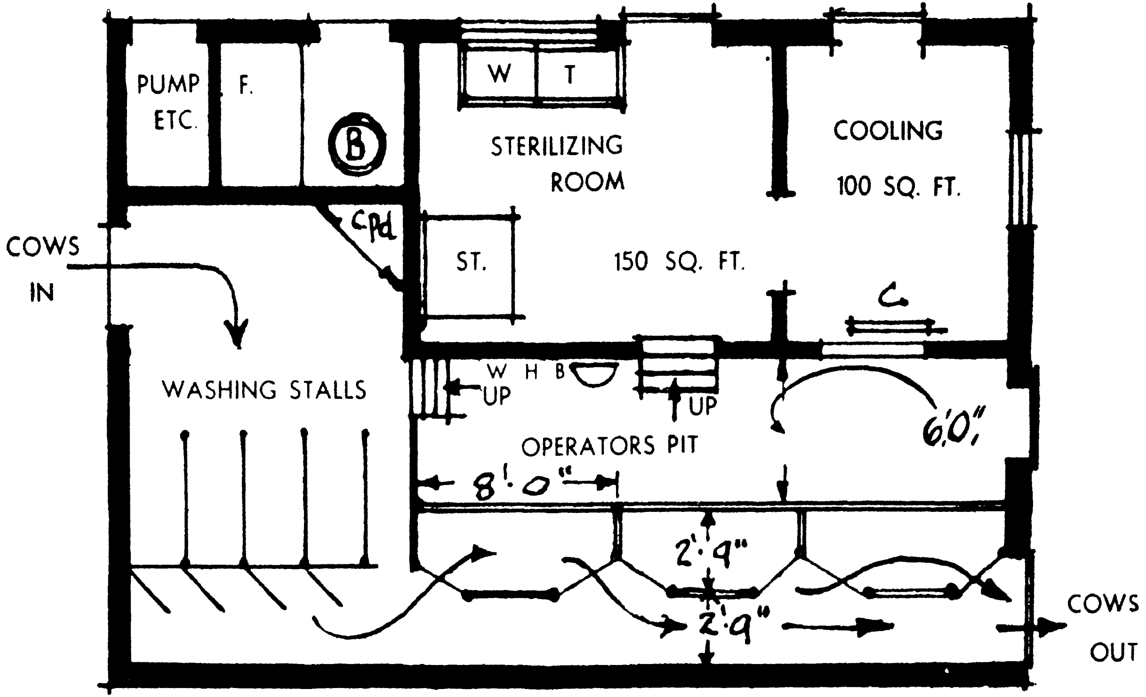


FIG. DF 7.—*Single-line Tandem Parlour with Dairy Adjoining.*

central position in relation thereto. In the case of the milking parlour system, the dairy must be immediately adjoining, in fact there is no objection to a doorway direct from the parlour to the cooling room. Other matters which should receive consideration are (*a*) convenience for milk collection, (*b*) the shading of the cooling room windows and roof lights from the direct rays of the sun as far as possible, (*c*) provision for easy churn loading by raised platform ramps, (*d*) the avoidance of sites close to any source of contamination such as a manure heap with its attendant flies.

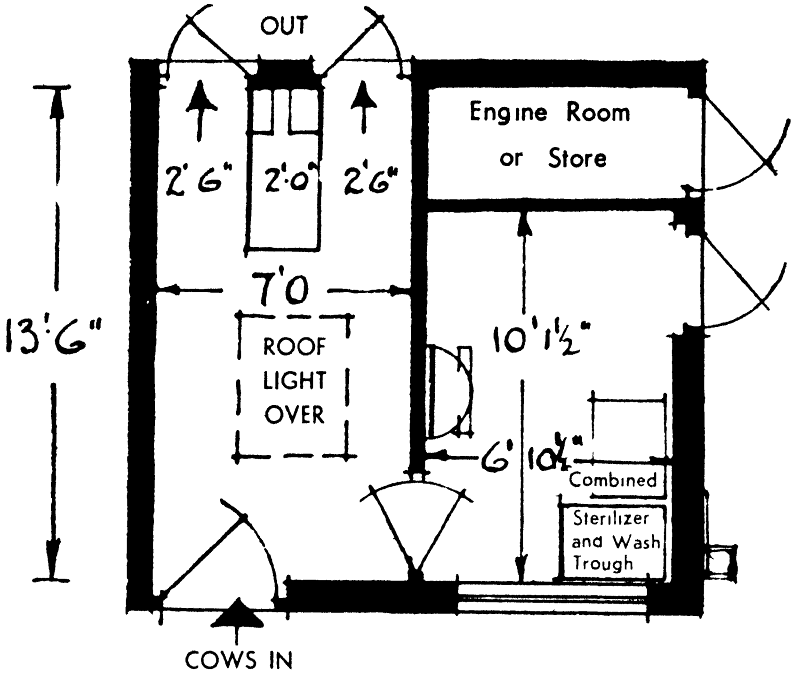


FIG. DF 8.—*Milking Parlour and Milk Room suitable for a Wholesale Producer with up to 14 Cows*

The size and arrangement of the dairy will vary to a considerable extent according to size of herd, method of milking, treatment of milk, power supply. The minimum sizes suggested as a guide by the Ministry of Agriculture are

Size of herd	*Milk receiving room (if required)*	*Milk cooling room* W	*Milk cooling room* R	*Washing and sterilising room* W	*Washing and sterilising room* R	*Boiler house (if required)*
Less than 20 cows			80	100	100	30
20 to 40 cows	40	60	120	120	150	40
Over 40 cows	40	100	150	150	200	50

W for wholesale contract   R for producer retailer

All areas in sq ft. The minimum height should be 8 ft.

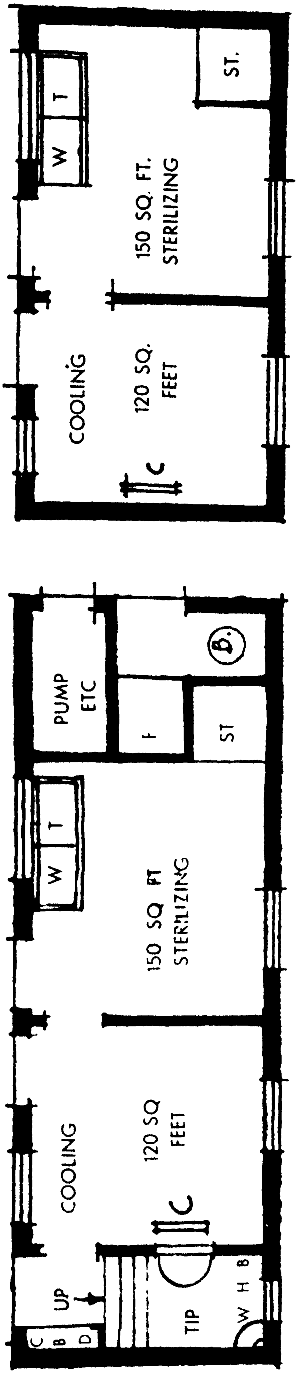
For the small herd there is no great objection in combining milk cooling and sterilising in the same compartment having a minimum area of some 100 sq. ft.

Some typical arrangements for different conditions are illustrated in Figs. DF 4, 6, 7, 8 and 9.

In the construction, hygienic considerations are paramount; the provision of smooth, impermeable interior surfaces, the elimination of dust-collecting ledges and surfaces or angles difficult to clean, and the provision of a reasonably well-insulated structure are of great importance. Floors are normally of good quality concrete laid to slope to an external gully, and reinforced with steel surface grids whenever full churns are moved. Walls should be smooth cement rendered or painted with a hard gloss paint. Glazed tiles and brick are used for some portions of the wall (for instance, at the back of a surface cooling where milking splashings will affect the cement rendering or painted surface), but are too expensive for widespread use. The angles of walls, both external and internal, and the junctions with the floor should be rounded. The roof, at any rate of the cooling room, should be lined and at least half of the window area should be made to open. The provision of flyscreens over opening windows is worth consideration.

(5) *Accommodation for other dairy stock.* Loose boxes provide a "general purpose" form of building and sizes vary from 100 to 200 sq. ft. according to their main use—whether for calving, for housing calves, young stock or bulls, or for isolation purposes.

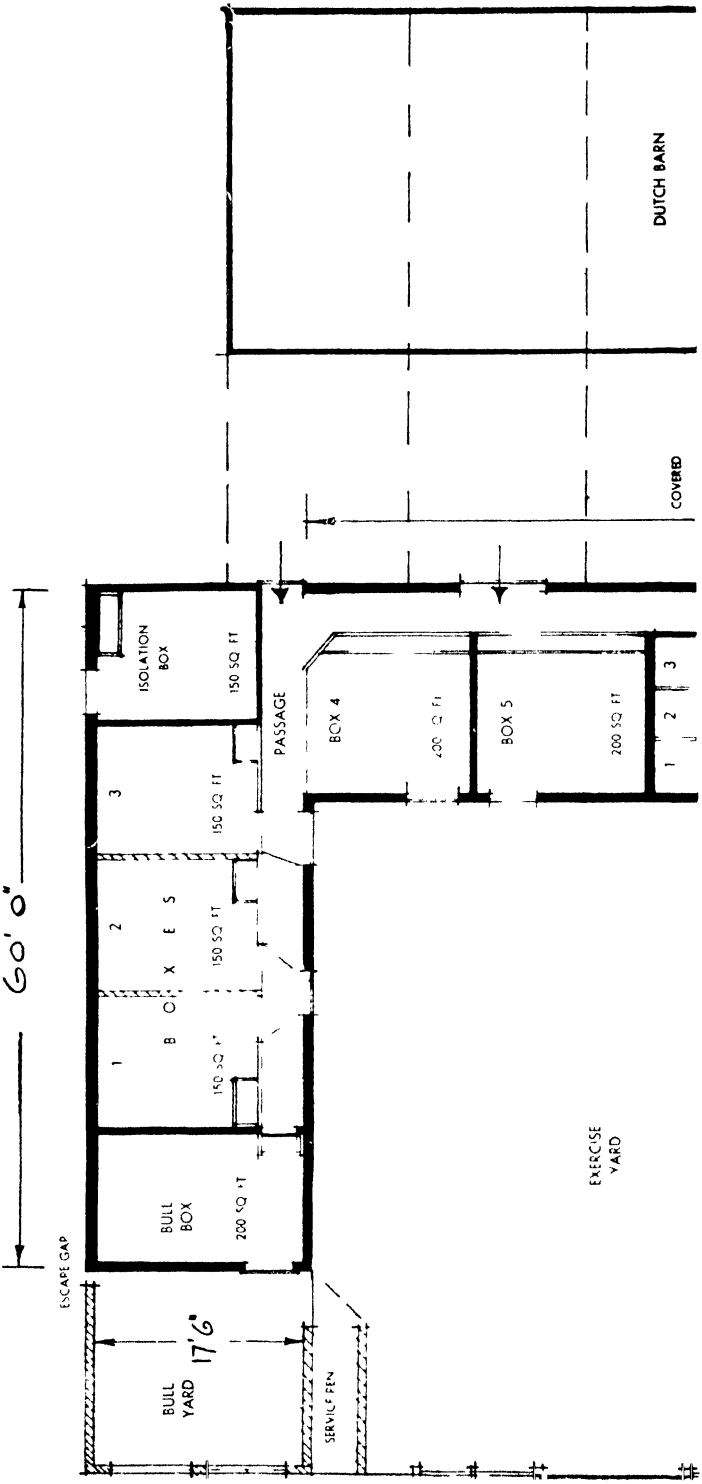
For young calves up to 3 months of age separate pens having an area of some 20 sq. ft. are desirable. For older stock up to some 2 years or more, larger pens or boxes or partially covered yards with a space allowance varying from 20 to 70 sq. ft. per animal according to age should be provided. A box of normal dimensions can be adapted to house some 6 or 7 young calves, but where



(B) With Electricity

(A) With Solid Fuel

FIG. DF 9.—*Dairy for the Larger Herd with Separate Cooling and Wash Rooms.*


DUTCH BARN
COVERED
ISOLATION BOX
150 SQ FT
PASSAGE
BOX 4
200 SQ FT
BOX 5
200 SQ FT
3
2
1
3
150 SQ FT
2
150 SQ FT
1
150 SQ FT
BOXES
BULL BOX
200 SQ FT
EXERCISE YARD
60' 0"
ESCAPE GAP
17'6"
BULL YARD
SERVICE PEN

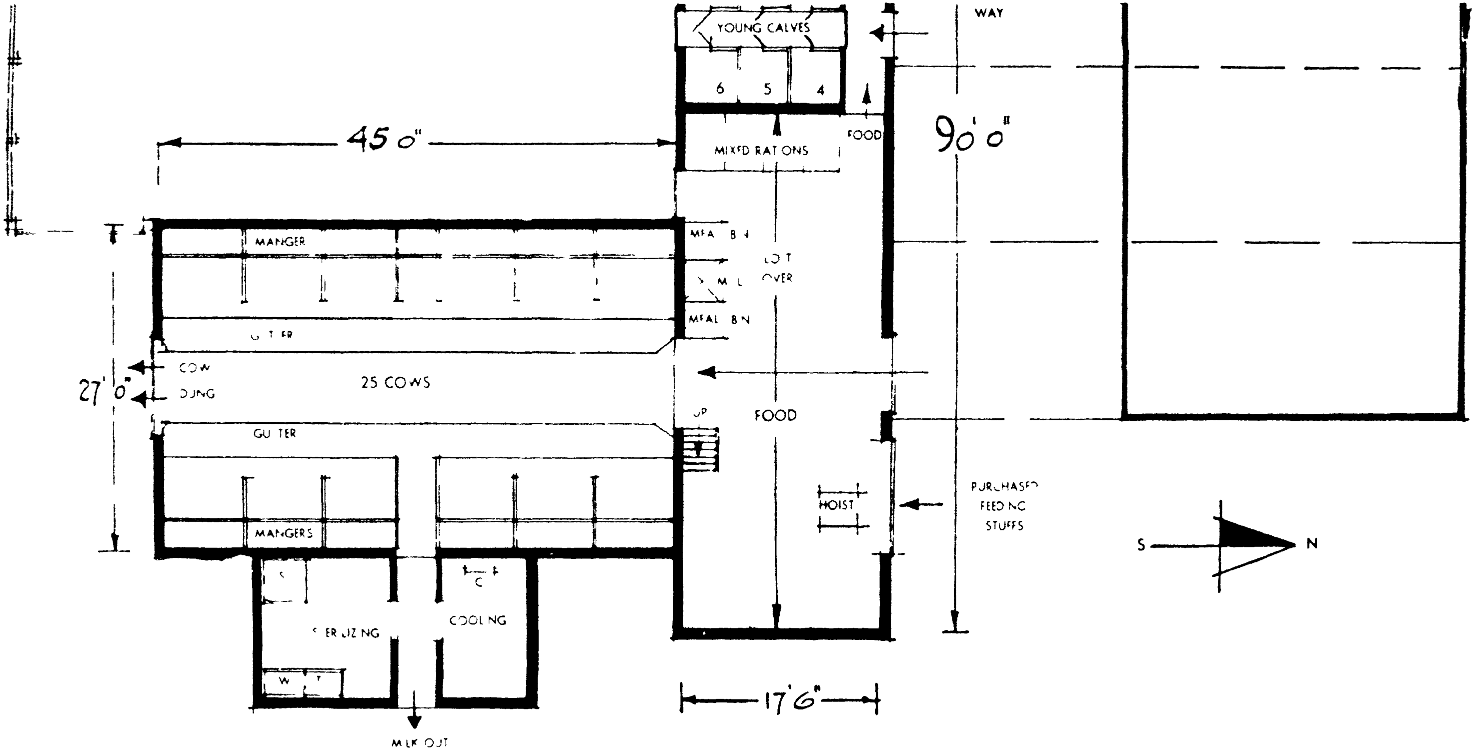


FIG. DF 10.—*Farmstead Layout*

numbers are appreciably greater a separate calf house has advantages. Particular attention must be given to insulation, ventilation and freedom from draughts in buildings used for young calves or for isolation purposes. The standard of construction and internal finish should be similar to the cowshed. Typical calf pen arrangementa are shown in the farm layout plan, Fig. DF 10.

III. Materials and Construction. Recent years have seen the increasing use of prefabricated forms of construction applied to farm buildings, particularly so in the field of concrete and steel structures. The British Standards Institution in collaboration with the Ministry of Agriculture have already prepared specifications for standard general purpose structures suitable for practically all types of farm buildings requirements. These structures consist essentially of asbestos cement roof sheeting fixed to steel or concrete roof members which are in turn supported by steel or concrete uprights at 15 ft. intervals. There are three standard widths, *viz.* 17 ft. 6 in., 27 ft., and 32 ft. 3 in. inside measurement and four varying heights of 8 ft., 10 ft., 12 ft. and 16 ft. from ground to eaves. The 17 ft. 6 in. structure is suitable for single row cowsheds, milking parlours, dairies and boxes, the 27 ft. for double row cow sheds without feeding passages, and the 32 ft. 3 in. building for double row cowsheds with feeding passages, and for covered yards.

The dimensions of all the buildings illustrated in this section have been selected to suit the dimensions of the General Purpose Buildings.

Since the weight of the roof is carried by the uprights, the thickness and strength of the intervening wall panels can be reduced and for this form of " post and panel " construction, 4½-in. brickwork, 4-in. and 6-in. hollow clay blocks, concrete slabs and blocks both solid and hollow can be used. Alternatively, the roof members only can be used equally well with the traditional type of load bearing solid brick wall. The possible snag in the use of the panel fillers mentioned above is that in some cases the wall does not prove entirely rainproof unless treated externally with a waterproof paint or with a cement rendered or roughcast finish. Hollow blocks give better insulation than the solid types, whilst for dairies or calf houses normal brick cavity wall construction is very suitable. For adult dairy stock, shelter from draughts rather than a high interior temperature is the important factor, and insulation in walling and roofing materials is not a matter of great importance.

Some examples of precast concrete structures are illustrated in Fig. DF 11. This form of construction eliminates all maintenance and painting work necessary on steel roofs and gives a roof space clear of obstruction or dust collecting ledges. One disadvantage is their heavy weight and the resultant difficulty of handling the various concrete posts and roof members, but the development of prestressed concrete is likely to achieve a considerable reduction in the dimensions (and therefore in the weight) of the various members.

For roofing purposes the various types of asbestos cement sheeting generally provide a very satisfactory finish. Tiles and slates necessitate the use of a relatively large quantity of timber supports and are more expensive, but if used, the fixing nails should be of substance resistant to atmospheric corrosion, such as copper.

Concrete is normally used throughout for floor surfaces, but proper attention should be given to the selection and grading of materials, to the mixing, and the laying, if best results are to be achieved. For the portion of a floor on which livestock will be lying, the formation of a closed air space beneath the surface will give better insulation.

Ventilation and lighting. The internal atmosphere of all the building should be kept fresh and in a wholesome condition. Since the livestock buildings will be occupied for the most part only during the winter period when there is normally an appreciable difference between the internal and external temperatures, a natural system of ventilation is usually satisfactory. Recent experiments at the

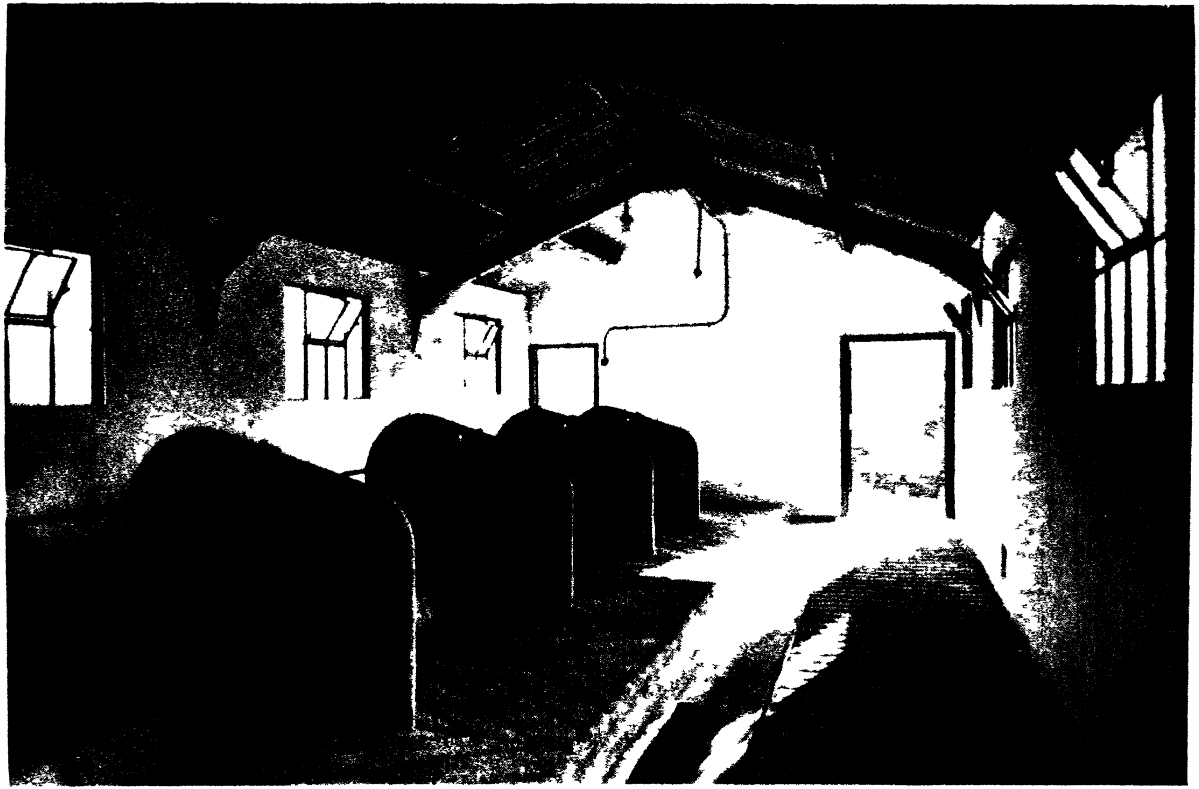
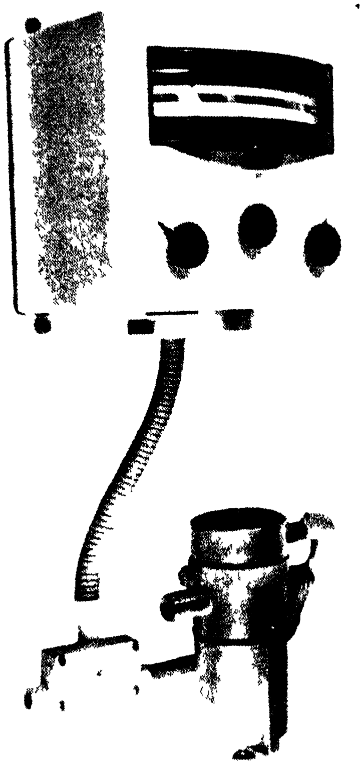


FIG DF 11 —" *Single Row* " *Cowshed of Precast Reinforced Concrete*



[By courtesy of Industrial and Scientific Instruments Ltd

FIG. DM 1.—*Detergent Strength Meter Type 5A, Showing Flow Type Electrode*

Hannah Research Institute indicate the importance of an adequate outlet having in the case of the cowshed a cross-sectional area of some 144 sq. in. per cow.

Ideally, the outlet should be adjustable and must be so shaped that down draughts will not occur. The inlet in the walls should be placed and designed to eliminate risk of draughts, and in the case of calf pens and boxes should be placed some 4 ft. to 5 ft. from the floor.

Considerable difference of opinion exists as to the area of inlet that should be allowed, but a figure of ⅓ of the outlet area may be taken as a general guide. Opening windows and doors supplement this allowance to varying degrees—in fact in the case of the dairy, windows placed at opposite sides of the building to provide a through air current often eliminate the necessity of any special outlet, although an air brick or other outlet near to the sterilising chest may be an advantage in the removal of surplus steam.

For natural lighting, suitable area allowances are about ⅛ of the floor area if side windows are being used, or $\frac{1}{16}$ of the floor area if roof lighting is employed. Very often a combination of the two arrangements is the best solution, particularly so in the double range cowshed. Windows should be placed at a high level to reduce risk of damage. Standard sizes of metal windows are available, of the hopper pattern, *i.e.* with the opening portion hinged at the bottom to open inwards, and the use of a protected metal finish is an advantage.

For roof lighting, perspex sheeting can be obtained in the same shapes as the various corrugated roof sheets and so can be fixed easily. Special asbestos cement sheets with an open panel to receive glass are also available. Both these methods eliminate the use of any lead flashing.

Both natural and artificial lighting (at the rate of about 100 watts per 15 ft. bay) should be located to give as far as possible uniform distribution throughout the buildings, but with greater concentration on the back of the cowstalls, on the cooler, and on the dairy cleaning equipment, so placed that the farm hands do not have to work in shadow.

Water supply and drainage. The recommended allowances for the dairy herd by the Ministry of Agriculture are as follows:

Cows	15 gal. per day	per animal
Cooling and cleaning	15 ,, ,,	
Young stock	5 to 10 ,,	

Emphasis has already been laid on the importance of a supply of water of suitable purity and quantity. Drinking bowls for each cow should be provided in the cowshed and boxes, water troughs in yards, and screw-nozzle draw-off taps throughout the buildings. For economy, waste cooling water can be carried up from the cooler outlet to a tank for storage and distribution for drinking and cleaning. A strong tubular type of cooler will be necessary.

The Ministry of Agriculture makes grants towards the cost of water supply to dairy farms.

The separating and storage of liquid manure from the cowshed which would otherwise run to waste is a matter worthy of consideration, provided an automatic system can be employed, firstly, to keep washing down water from the liquid manure drain and, secondly, to distribute the liquid manure over solid manure and bedding. The dungstead (preferably roofed to exclude rain) and the liquid manure tank should adjoin and an electric motor and pump—float-switch operated—should be fitted to the tank so that periodically the liquid is pumped automatically over the solid manure heap. One of the advantages of the covered yard system of housing is that as urine will be absorbed by the bedding, that there is then no loss of manurial value and a drainage system is unnecessary.

Refs.: "Farm Buildings", Post-war Building Studies, No. 17; "Scottish Farm Buildings", Post-war Building Studies, No. 22; "Fixed Equipment of the Farm",

DAIRY FARMING

Leaflet No. 1, Cowhouses; No. 3, Farm Dairies; No. 5, Milking Parlours; No. 16, Bull Boxes (all H.M.S.O.); Concrete for the Dairy Farmer, "Farm Construction" Leaflet No. 1, Dutch Barns; No. 2, Implement Sheds; No. 3, Reinforced Concrete Framing for Farm Buildings; No. 4, Milk Parlours; No. 5, The One-Room Dairy; No. 6, The Combined Milking Parlour and Dairy (all Cement and Concrete Association); Findlay, "Experiments on the Ventilation of Cattle Byres", *JAS*, **38**, 411; "Labour Organisation in Milk Production", Bull. No. 32, Cambridge University Economics Department of the School of Agriculture; Wooley (1954), *Planning Farm Buildings*.

DAIRY FARMING. *See* Agriculture; Breeding; Dairy farm buildings; Feeding; Management.

Ref.: Russell (1950), *JSDT*, 4, 4.

DAIRY INDUSTRY—GENERAL DATA. The dairy industry is one of the largest of British industries. The total capital value of the dairy farming industry has been estimated at over £800,000,000; it employs about 400,000 workers and produces about 1,725,000 gal. of milk annually in England and Wales, equivalent to 1,000,000 tons of dry weight food which is 100 per cent. digestible. The average price per gal. in 1952-53 was 3s. 2d. and the total sale value about £275,000,000. At this time, of about 24,500,000 acres in England and Wales, about 10,500,000 acres were down to permanent grass and 14,000,000 acres were arable, and of a total of nearly 8,000,000 cattle about 3,500,000 were cows and heifers, of which about 2,250,000 would be in milk. An average cow produces about 60 cwt. or 650 gal, in a year, equivalent to five or six times its own weight. Of the sales through the Marketing Scheme, 83.8 per cent. was sold as liquid, and the remainder converted to cheese (8.9 per cent.), condensed milk (2.9 per cent.), butter (1.9 per cent.), milk powder (1.5 per cent.), fresh and tinned cream (0.8 per cent.), and to other products (0.2 per cent.).

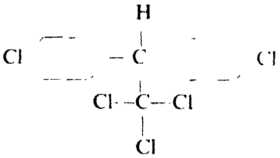
The distributive side is no less important; it employs nearly 100,000 workers and has a capital value of about £150,000,000. The retail sales of liquid milk in 1952-53 were £250,000,000, and of dairy produce about £40,000,000. It has been calculated that it takes one man equivalent to bring 15 gal. of milk daily from the cow to consumer. *See* Agriculture; Milk Marketing: Utilization.

Refs.: Roadhouse and Henderson (1950), *The market-milk industry*, Enock, Cronshaw; Walworth; Davies, J. L. (1944), *CI*, p. 10; Williams.

DAY TO DAY VARIATIONS IN COMPOSITION. In the absence of any obvious reasons, *e.g.* sudden changes in weather, calvings, feed, etc., the composition of the milk from a herd is fairly constant. The most likely cause of variations in fat is changes in the time of milking (*see* Collins rule).

The milk of individual cows, however, may show appreciable changes in both fat and solids-not-fat content, due to diurnal changes in health of the animal. *See* Composition, factors affecting.

D.D.T.



dichlordiphenyltrichlorethane

This substance is the best known of insecticides and has many advantages over others, chiefly because it is odourless, cheap, stable, rapid in action, and of very low toxicity.

As flies are a nuisance to cows and a source of contamination to milk, treatment with D.D.T. preparations, which contain pyrethrum for the knock-down effect, should be carried out where advisable. The substance may be sprayed, painted, or volatilised by a candle of the " fire-work " type. *See* Insecticides.

Refs.: West and Campbell (1950), *DDT and newer persistent insecticides;* West and Campbell (1946) *DDT—The Synthetic Insecticide*, London.

DEAD WEIGHT. *See* Pigs.

DEAMINATION. The removal of an amino group (NH_2) from amino acids or other nitrogenous substances.

DECENOIC ACID. An unsaturated fatty acid $C_7H_{15}.CH = CH.COOH$ occurring in traces in butterfat. *See* Fatty acids.

DECOMPOSITION. A general term for the breakdown of animal and plant tissue by micro-organisms, enzymes, etc. It has acquired a particular meaning in the sense of *putrefaction* which is breakdown accompanied by the production of diamines and other unpleasant stinking substances. Such changes are favoured by neutral or mildly alkaline conditions and repressed by acidity. This is the reason why milk and milk products so rarely decompose in the putrefactive sense. *See* Flavours ; Stability.

DEFECTS. *See* Butter ; Cheese ; Coliforms ; Condensed milk ; Flavours ; Milk powder ; Stability ; Taints.

DEFINITIONS.

Ampère = Unit of electric current. Deposits 0·001118 g. silver per sec.
Angström unit = $\frac{1}{10,000,000}$ mm.
B.Th.U. (British thermal unit) = Quantity of heat required to raise 1 lb. water 1° F (= 252 calories).
Calorie (small) Quantity of heat required to raise 1 g. water 1° C.
Calorie (large) kilocalorie = 1,000 calories.
Centrifugal force = 0·0034 WRN^2 = 0·00034 × wt. in lb. × radius in ft. × no. rev. per min.
Coulomb Quantity of electricity transferred by a current of 1 amp. flowing for 1 sec.
Dyne = Unit of force. It imparts an acceleration of 1 cm./sec./sec. to 1 g.
g = acceleration due to gravity = 32·16 ft. per sec. per sec.
Eh Voltage of a half cell referred to a normal hydrogen electrode.
Erg = Unit of work. 1 dyne acting through 1 cm.
Gram = unit of mass or matter = weight of 1 c.c. of water at 4° C. ÷ g.
Horse power = 33,000 ft. lb. per min. = 0·746 Kw.
k (insulation) = B.Th.U. transmitted per hr. per square ft. per ft. thickness per °F. temperature difference.
Kilowatt = 1000 Watts.
Kinetic energy = $\frac{1}{2}mv^2 = \frac{\text{mass} \times (\text{velocity})^2}{2}$.
$\mu = \frac{1}{10,000}$ cm. $m\mu = \frac{1}{10,000,000}$ cm.
Mass = Amount of matter in a body. (*See* Gram; Mass.)
Mho = Unit of electrical conductivity = $\frac{1}{\text{ohm}}$.
Momentum = mv = mass × velocity.
Ohm = Unit of electrical resistance. 1 volt produces a current of 1 amp. through a resistance of 1 ohm.
*p*H = Negative logarithm of concentration of hydrogen ions in g./l.
$r\text{H} = \frac{\text{Eh}}{0·03} + 2p\text{H}$.
Volt = Potential producing a current of 1 amp. in a resistance of 1 ohm (international units).
Watt = volt × amp.
Weight = mg = mass × acceleration due to g.

DEGREES. (i) *Acidity.* Degrees of acidity as used in the U.K. usually refer to the number of $\frac{1}{10}$ ml. of $\frac{N}{9}$ sodium hydroxide required to " neutralise " 10 ml. milk. Thus, if 1·4 ml. of NaOH are required, the milk is said to have 14° of acidity. This figure is thus 100 times the " per cent. lactic acid ". Other degrees are as follows: Dornic: The no. of ml. 0·046 N $Ca(OH)_2$ (saturated lime water at 15° C.) for 100 ml. milk. Soxhlet-Henkel: The no. of ml. 0·25 N NaOH for 100 ml. milk. Richmond: The no. of ml. N/10 NaOH for 100 ml. milk. Thus the acidity of fresh milk is about 14° (lactic acid) 30° Dornic (D), 7° Soxhlet-Henkel (S-H) or 17° Richmond. *See* Acidity.

(ii) *Density and specific gravity.* The density of a liquid is the weight of unit volume and has the dimensions ML^{-3}. Specific gravity is usually expressed as the ratio of the weight of a given volume of the liquid to the weight of the same volume of water and is therefore dimensionless. Thus, the specific gravity of milk is on the average 1·032 and this is commonly called 32° of gravity. *See* Solids-not-fat.

(iii) *Temperature.* The range between the freezing-point and the boiling-point of water is divided into 100° Centigrade or Celsius, 180° Fahrenheit or 80° Réamur. Thus 1° C. = $\frac{9}{5}$° F. = $\frac{4}{5}$° R. *See* Thermometric scales.

Refs.: Davies; Richmond.

DEHYDROGENASES. Enzymes which catalyse the oxidation of substances in the presence of ordinary oxygen or oxidants (formerly called oxidases). *See* Enzymes.

DELIQUESCENCE. The absorption of moisture from the air, the material becoming visibly moist.

DENMARK.

Refs.: Mathiassen (1949), *IDC*, **4**, 533; Jørgensen, 760; Kjaergaard, 775; Schak *et al.* (Editors) (1948), *Handbook on the Danish Dairy Industry*, Odense; Skovgaard (1946), *Survey of Danish Agriculture*, Copenhagen; Bond *et al.* (1928), *British Farmers in Denmark: Mission of Inquiry into Denmark's Agricultural Methods*, London.

DENSITY OF MILK. The density of milk is about 1·032 at 60 F. and is controlled by the fat content (sp. gr. 0·9) and solids-not-fat content (sp. gr. c. 1·6). *See* Degrees; Lactometer; Solids-not-fat; Total solids.

DENSITY OF MILK SOLIDS. Average values are: Fat 0·93, solids-not-fat 1·616, lactose 1·666, protein 1·346, minerals 5·5. A recent value for air-free full cream milk solids of 27 per cent. fat is 1·27 (Lea and Gane (1946), *JDR*, **14**, 400).

DERBY. *See* Cheese, p. 189.

DESCALING. The removal of milk stone (calcium salts, etc.), or of rust and other corrosion oxides, etc., from metals by acids. Usually a weak acid, such as phosphoric, or a strong acid in dilute solution with a suitable inhibitor (p. 543) is used. It is most important to flush out with alkali and water after descaling as otherwise residual acid will lead to corrosion. *See* Calgon; Cleaning; Detergents.

DESIGNATED MILKS. The officially designated milks are: Tuberculin-tested, T.T. (Farm bottled), Pasteurised, Sterilised. The requirements are briefly as follows:

Tuberculin-tested. The milk must be from a tubercle-free herd completely isolated from all other cattle. It must be delivered in a sealed non-ventilated container.

Tuberculin-tested (Farm bottled). As above but it must be bottled on the farm, the cap overlapping the mouth of the bottle.

These two grades must satisfy a methylene blue test (4½ hr. May to Oct.; 5½ hr. Nov. to April).

Pasteurised Milk. Milk pasteurised by approved method under license.

This must satisfy a methylene blue test (½ hr. after 17 hr. storage at atmospheric shade temperature) and a phosphatase test. T.T. (Farm bottled) may be regarded as a special type of T.T. milk and T.T. (pasteurised) as a special type of pasteurised milk.

Sterilised milk must pass a turbidity test.

(Formerly) Accredited Milk. Milk produced from cows examined by a veterinary surgeon every 3 months. Cows must be maintained free from others and diseased cows removed at once. This grade was abolished 30th Sept., 1954.

See Milk (Special Designations) Orders; Ireland, Northern; Legal aspects; Pasteurisation; Scotland.

DETERGENTS AND DETERGENCY. Detergency in the dairy industry has become a specialised branch of cleaning, a very high standard being required. The objects to be cleaned come mainly under the following headings: (1) storage tanks, holder pasteurisers, and other large receptacles; (2) churns; (3) milk pipe lines; (4) high temperature-short time pasteurising plants; (5) bottles; (6) floors and walls. These groups will be discussed in greater detail later.

The prime object of detergency in the dairy is to remove milk residues and other material which can provide food for bacterial growth. Except in the case of certain detergents which are strongly alkaline and can be used at a high temperature, little actual killing of organisms is done by detergents and the action is largely one of providing a physically clean surface which is an unsatisfactory environment for micro-organisms and removing from this surface the bacteria-laden deposits.

In some cases the cleaning by detergents is followed by sterilisation either by steam or chlorine, the latter being usually in the form of sodium hypochlorite solution. In no case must the sterilising procedure be regarded as modifying or superseding the detergency treatment, otherwise the food-rich environment will persist after this treatment and afford a good breeding ground for new colonies of organisms. The nature and condition of the deposit or soil, and the composition and condition of the surface, are both important factors in detergency.

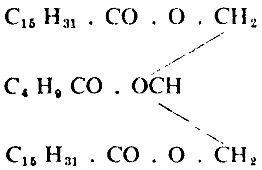
The milk residue which has to be removed will vary according to the treatment the milk has received in the vessel, or pieces of plant; thus the cleaning of a raw milk tank will be an easier task than cleaning a holder type pasteuriser, while this in turn will not present the difficulties which can be met with in plate type H.T.-S.T. plants. Milk residues will vary in their condition according to their location and the age of the deposit, from easily removed liquid residues to hard " baked on " deposits of milkstone.

The nature of the surface is important for two reasons. Firstly, the material may impose limitations on the kind of detergent used, *e.g.* aluminium requires a detergent which will not cause corrosion and must not contain caustic alkalis, while stainless steel can be cleaned with the most powerful detergents. Secondly, the physical condition of the surface—whether polished, smooth, or rough—will determine to some extent the degree of adhesion of the deposit, and the degree to which bacterial infection will survive after the cleaning process. Hard, highly polished surfaces are the ideal ones for the dairy, glass being probably the most satisfactory, but obvious limitations prevent its use except in a few places. Care should be taken with the use of any abrasive material—the scratching of metal surfaces being very conducive to the harbouring of bacterial growth. In fact, the use of abrasive materials should be restricted to an absolute minimum. In all cleaning operations the first thing to be done is to rinse with warm water—not hot water—and thus remove all loose material and some of the butterfat which may be partly liquefied by the warm water. Then the detergent solution is used either by soaking, swilling, swabbing, brushing, or jetting, and this must be followed by a thorough rinsing in clean cold water. Inspection at this stage should show a visually clean bright surface. A final sterilising operation is necessary for all equipment and utensils except bottles, which are subjected to high caustic alkalinity and high temperature, and this may be achieved either by steam, boiling water, or chlorine. This is the general routine for all dairy cleaning with additions and variations for the specific tasks which will be dealt with later.

Modern dairying detergents are based on the following alkalis and salts: caustic soda, sodium metasilicate, sodium orthosilicate (and sometimes the more siliceous silicates, *e.g.* water glass) sodium carbonate, trisodium phosphate, tetrasodium pyrophosphate, sodium hexametaphosphate, soaps, and organic wetting agents.

Sometimes the crude alkali is used alone with no other ingredients, but research has shown that detergents for various purposes require special products which are not to be found in any one substance. Detergent manufacturers who specialise in graded detergents for the dairy industry have produced balanced detergents which incorporate the following properties which are essential for dairying detergents: saponification or hydrolysis of milk fats and proteins, emulsification and deflocculation, wetting, rinsibility, buffering, and sterilising power. Although this classification has not been arranged in any particular order of importance, it is instructive to take it in sections and discuss the principles underlying these properties.

(1) ***Saponification.*** This is sometimes referred to as hydrolysis and is largely a function of the caustic alkalinity of the detergent. Esters are hydrolysed by caustic alkalis according to the general formula:
$R\,.\,CO\,.\,O\,.\,R' + NaOH \rightarrow R\,.\,COONa + R'\,.\,OH$ (R may have a form such as $C_{15}H_{31}$): a typical fat (ester) would have the formula:



$C_{15}H_{31}\,.\,CO\,.\,O\,.\,CH_2$
$C_4H_9\,CO\,.\,OCH$
$C_{15}H_{31}\,.\,CO\,.\,O\,.\,CH_2$

Thus, in a fat which is a glyceride of the type indicated above, hydrolysis would result in two molecules of sodium palmitate, one molecule of sodium butyrate with, of course, one molecule of glycerol.

A reasonably high temperature and high *p*H are required for the hydrolysis of fats and this is, therefore, one good reason why detergency operations in the dairy industry should be carried out at as high a temperature as possible. Saponification will also be assisted by emulsification and a lowering of interfacial tensions will greatly aid the process. In point of fact, not very much saponification takes place because of the limited time of contact, except, perhaps, in the detergent tank of a bottle-washing machine; but even the little which takes place is valuable and assists the cleaning process because of the formation of soaps which tend to lower the surface and interfacial tensions of the solution resulting in an increase of wetting and penetrating power. Saponification should, therefore, always be aimed at in the maximum degree possible.

It should be mentioned that the casein of milk may also be affected by this hydrolytic fission, but in a lower degree, and here the products may be ammonia, carbon dioxide, and amino-acid fragments due to the fission of the protein molecules. Generally speaking, however, these may not constitute more than a small fraction of the total matter actually hydrolysed.

It has been observed that caustic alkalinity is necessary for the purpose of saponification, and it is necessary at this point to consider the question of alkalinity with its associated yardstick *p*H. It is important to emphasise that a high *p*H does not always mean a high concentration of alkali, although it means a high concentration of hydroxyl ions. What the *p*H index figure shows is the degree of acidity or alkalinity of an aqueous solution, and it is not a measure of the total amount of the particular material in solution. Neutral *p*H is about 7 and alkaline solutions have their *p*H figures between this and 14, while acid solutions show a *p*H value below 7 and tending towards zero as the degree of acidity increases. The *p*H index is the logarithm of the reciprocal of the hydrogen ion concentration and is, therefore, a logarithmic scale, so that *p*H 4 will be 10 times as acid as *p*H 5, that is to say, there actually will be in such a solution 10 times the number of hydrogen ions at *p*H 4 as at *p*H 5.

Kinds of Alkalinity. If an alkaline solution which contains, for example, certain amounts of caustic soda, sodium carbonate and trisodium phosphate is titrated with a standard acid using phenolphthalein as indicator, a smaller amount of acid will be used to reach the end-point than if methyl orange is the indicator. Thus, with phenolphthalein as indicator the pink colour disappears at about *p*H 8·4, but with methyl orange, more acid will be used before the colour change takes place about *p*H 3·5.

This simple example shows the difference between caustic and carbonate alkalinity. On titrating to the phenolphthalein end-point " caustic alkalinity " is obtained, and in the case of the solution mentioned above, this is represented by the whole of the caustic soda present, one half of the sodium carbonate and one third of the trisodium phosphate.

If, after the decolorisation of the phenolphthalein a few drops of methyl orange are added, and the titration continued, the methyl orange end-point will show the " carbonate alkalinity ", which will be contributed by the other half of the sodium carbonate present and another third of the trisodium phosphate. The remaining third of the trisodium phosphate after the methyl orange end-point, will be monosodium dihydrogen phosphate, which is an acid salt, and which in solution has a *p*H less than 4, and hence plays no part in a titration with methyl orange as indicator.

This difference between carbonate and caustic alkalinity can be explained as follows: If a solution of sodium carbonate is titrated with acid in the presence of phenolphthalein, the phenolphthalein decolorises at about *p*H 8·4, and the reaction which has taken place at this point may be represented as follows:

$$Na_2CO_3 + HCl = NaHCO_3 + NaCl$$

and the titre represents caustic alkalinity. The sodium carbonate has been converted into sodium bicarbonate which is almost neutral in its reaction. After the titration to the methyl orange end-point at about *p*H 4, the sodium bicarbonate is also converted into another molecule of sodium chloride with the final evolution of carbon dioxide and loss of water. Thus, sodium carbonate will give half its alkalinity to be titrated as " caustic alkalinity ", while the other half is titratable to methyl orange and is " carbonate alkalinity ".

These facts show why a detergent solution which has a high caustic alkalinity when freshly made up may, during the detergency process, lose a proportion of it by neutralisation of acid milk residues and saponification while a further proportion is converted to carbonate alkalinity.

This aspect is of primary importance in machine bottle washing where the interiors of the bottles are not subject to manual cleansing and must rely upon the detergency and sterilising powers of a solution of high caustic alkalinity to bring about adequate cleansing and disinfection, both of which are of equal importance.

(2) *Wetting and surface activity.* Detergency may be regarded as a competition between the unwanted dirt or grease and the detergent solution for the underlying surface. A perfectly clean glass or metal surface permits water to spread readily upon it because the surface of the glass or metal attracts the water molecules more than they attract each other. If the surface is covered by a film of grease, water will not spread over it, but will contract into patches or globules, since the water molecules will attract each other much more than they will be attracted by the grease.

In practical detergency the problem is to ensure the removal of the grease by the process of emulsification, but for emulsification to take place, the first essential is that the detergent solution should " wet " the surface thoroughly and should penetrate into any gaps or crevices in the grease film as a preliminary to breaking it up ready for emulsification. Obviously, the detergent solution cannot do this if it does not spread over and " wet " the surface, and in order for this to be possible the surface energy of solution must be reduced to a point where this condition is permitted. The wetting power of a solution can be determined by measuring its surface tension by one of a number of well-tried methods. In the case of solutions which contain soaps or wetting agents, the mechanism of surface tension reduction is relatively simple to explain ; in the case of solutions of caustic alkalis with mixtures of certain alkaline salts, reductions of surface tension occur which are difficult to reconcile with known facts.

Surface Tension. A liquid has internal cohesive forces which tend to minimise its surface area, and in the surface layer each molecule has forces operating on five sides only, whereas a molecule in the bulk of the solution has attraction from all sides. Thus, at the surface there will be a force generally directed towards the interior of the solution which, for any liquid, will reflect the residual energies or attractive powers of the molecules. This is called the free energy of the surface, and would normally be recorded in ergs per cm.^{2}. It has been found more convenient, however, to express this quantity as a force along a line in dynes per cm., but any idea that the surface of the liquid has a tensile skin which is in a state of tension parallel to the surface, should be excluded.

One of the more simple and instructive methods of measuring surface tension is by the comparative method of the " drop pipette ". The unknown surface tension is found by comparison with a liquid, the surface tension of which is already known. Drops of the liquids are allowed to fall, a definite number of them, into a weighed bottle ; since the drops will be all of the same size for a given liquid, the total weight divided by the number of drops will give the mass of each individual drop. The mass of each drop of a certain volume is related to its surface tension because of the internal cohesive forces mentioned above, and so by comparing the unknown with the known solution, its surface tension can be obtained by means of the following formula : $\begin{matrix} S_1 & M_1 \\ S_2 & M_2 \end{matrix}$ where S is surface tension and M the mass of one drop. The surface tension of water is about 72 dynes per cm. and in practical detergency it is important to reduce this to as low a figure as possible in order to achieve good wetting and penetration. The surface tensions of other liquids are as follows : benzene, 28·8 ; chloroform, 27·1 ; ether, 17·0 ; mercury, 485·0. It will be seen that the liquid metal mercury has an extremely high surface tension, while organic liquids such as benzene, chloroform, and ether have very low free surface energies, all facts which reflect the different powers of attraction associated with the molecules of the specified substances, the " internal cohesive forces " referred to above. A word of explanation as to the fundamental nature of this attraction may be useful at this point. If a molecule contains an atom or a group which is very reactive, the residual affinity associated with that group will cause the molecule to have higher powers of attraction than would be the case if that atom or group were not present in the molecule. Consequently, liquids which consist of molecules with highly reactive groups have greater internal cohesive forces and surface tensions than those which have not. For example : ethyl alcohol C_2H_5OH with a slightly reactive —OH group has a surface tension which is lower than that of the closely related acetic acid with its much more strongly reactive —COOH group.

Water, which may be regarded as H . OH thus consists solely of two highly reactive groups, and it is not surprising to find that it has a high surface tension. Liquids like petrol, benzene, and carbon tetrachloride have very low surface tensions, but even here the rather more reactive benzene with a surface tension of

28·8 dynes is further up the scale than the less reactive cyclohexane (25·3 dynes) which has the same number of carbon atoms, but which does not have the reactive double bonds of benzene.

In detergency the surface tension of water can be lowered readily by the addition of a small quantity of a wetting agent, and in practice this method has become of primary importance, so that a consideration of the underlying principles in some detail is worth while.

Wetting Agents. Chemically these compounds usually consist of a paraffinic or hydrocarbon chain which is strongly hydrophobic in character, and a hydrophilic polar group such as $—SO_2O^-$ or $\equiv N^+$. Sometimes the hydrophilic group consists of glyceryl residues and is non-polar in character. Those wetting agents which have polar groups of the COO^- or $—SO_2O^-$ class are known as anionic wetting agents, while those which rely on $\equiv N^+$ for their solubility in water are classed as cationic, the non-polar glyceryl types being, of course, non-ionic.

Thus these compounds will be seen to consist of a water attracting group and a water repelling chain, so that one part of the molecule has a tendency to dissolve in water and the other part a tendency to remain out of solution. The greater the proportion of the water repelling chain in the molecule, the more reluctant is the molecule to remain in the bulk of the solution, and if the chain becomes too long, solubility will diminish until eventually an insoluble compound is obtained, and this, of course, would be of no use in detergency. Accordingly, in wetting agents the water repelling chain is within the limits of 8 and 20 carbon atoms in length. Below 8 carbon atoms the water attracting $—COONa$, $—SO_2ONa$ or $\equiv N.Cl$ group predominates in effect, so that below this number the molecule becomes progressively less efficient as a wetting agent.

Adsorption. On being dissolved in water, the molecules of a wetting agent are immediately attracted to the surface of the solution because the water repelling part of the molecule is more powerful in its effect than the water attracting salt portion, so that the molecules are always trying to escape from the water molecules. They cannot do this entirely because the hydrophilic salt grouping is strongly attracted by the water molecules, thus providing a kind of anchor which keeps the wetting agent molecule in solution. The result of this behaviour is that the surfaces of the solution become covered with a layer of wetting agent molecules, *the chains lying flat in the surface* so that the surface exhibits the free energy not of plain water, but of an organic liquid such as a paraffin normally is. The surface tension of the wetting agent solution is, therefore, found to be of the order of 30 to 40 dynes per cm. showing a great reduction from the 72 dynes of water. The phenomenon of the migration of such molecules to interfaces is described as the adsorption of the molecule, and the degree of surface activity for any soluble molecule is related to its rate of migration to the surfaces. Obviously, if a molecule has a large hydrophobic paraffinic chain, it will overcome the attraction of the water molecule for the water attracting part much more quickly than will a shorter chain compound, and in consequence its speed of migration will be greater because the $O—SO_2ONa$ or similar grouping will not have the same retarding power (Fig. D1).

Certain detergent mixtures when dissolved in water to make a 1 per cent. solution show static surface tensions which are lower than the surface tension of water. The reason for this is rather obscure, and at first the phenomenon was ascribed to the presence of organic matter. When the same formula was made up with purified substances the same result was observed ; this is contrary to theory, because the addition of an electrolyte to water tends actually to increase rather than lower the surface tension. A possible explanation would appear to be the formation of complex anions from the different anions afforded by the mixture, and these might exhibit some hydrophobic characteristics, become mildly surface active, and have only small powers of attraction in order to effect a reduction of surface tension. It is known, of course, that the repulsion of similar electric charges at a surface lowers the surface tension, but it is difficult to see how this state could arise under ordinary conditions, and so this would hardly supply a reasonable explanation. Another fact not at all easy to explain is why the interfacial tension between water and pure medicinal paraffin decreases as the *p*H increases. The suggestion has been made that the pure paraffin still contains traces of fatty organic acids which form soaps when the *p*H is sufficiently high, but this seems doubtful in view of the high state of purity in which this material can be obtained.

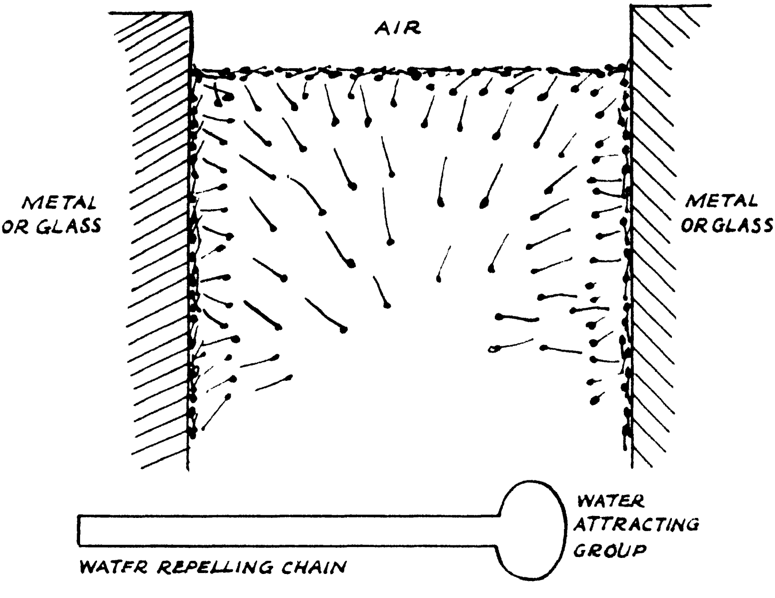


FIG. D 1.—*Diagrammatic Representation of the Adsorption of Surface-active Ions at Interfaces.*

(3) ***Emulsification.*** This is a most important factor where dairy detergency is concerned because all the milk fats cannot be hydrolysed, and unless the detergent solution has good emulsifying properties, cleaning will be poor. Just as it is not possible to draw a hard and fast line between a true solution and a colloidal solution, so it is not easy to say when the solution of one liquid in another ceases to be a true solution and becomes an extremely fine emulsion. Such cases depend upon the physical properties of the two liquids involved, but there are a number of cases where the appearance is that of a clear solution and the dispersed phase can be detected in the continuous phase only by the scattering of the rays of a beam of light projected into it. Towards one end of the scale we have a true solution, and towards the other a visual emulsion. Modern theory holds that an emulsion is brought about by the dispersed phase droplets having an adsorbed layer, perhaps of detergent ions and perhaps of ions and molecules contributed from other foreign substances. This adsorbed layer is charged and since all the droplets have similar charges, they repel one another and thus maintain the emulsion in an equilibrium. The addition of electrolytes often results in the upsetting of this equilibrium by the neutralisation of the charges of the adsorbed surface layer, resulting in the coalescence of the droplets and the subsequent breaking of the emulsion. The more finely dispersed the emulsion, the better will be the detergency, but it must be borne in mind that in a fine emulsion the interfacial surfaces possess a greater area than in a coarse emulsion, and so the former will

result in the adsorption of more detergent ions than the latter. Another point which is worth while noticing at this juncture is that some of the milk fat can dissolve in any soap micelles which may be formed as the result of saponification of the fats. A considerable amount of work has been done in recent years on this question of micelle formation and it has been fairly well established that this actually takes place. The hydrophilic (*i.e.* water attracting) polar (*i.e.* electrically charged) group of the soap molecule is regarded as lying on the periphery of a sphere, while the hydrophobic (*i.e.* water repelling) paraffinic (*i.e.* inert) part of the molecules is generally directed towards the centre of the sphere. It is then assumed that milk fat molecules without any polar or hydrophilic groups can dissolve in the paraffin-like part of the soap molecule within the micelle.

Colloidal activity and deflocculation may be mentioned here. A colloid is a non-settling suspension of finely divided particles which may be regarded as a continuation of the simple solution system terminating in discrete and flocculated particles. Again, all degrees of dispersion can exist between the true solution and the insoluble particle. Materials which have the ability to break up a solid mass into small particles and disperse them through the bulk of the solution are known as *deflocculating agents.* Efficient wetting of the solid is necessary to initiate deflocculation. It is of great importance to keep in suspension particles of solid substances which the detergent removes from the surface being cleaned. Some workers consider that deflocculation resembles emulsification in that it depends primarily on the formation of a barrier about the dispersed particles which is thicker than the distance at which surface attractive forces manifest themselves. Solid particles precipitated from hard waters by alkalis can be prevented from depositing as scales if the detergent has good enough deflocculating properties. Silicate solutions of low alkalinity (*e.g.* water glass) are very good for this purpose.

(4) ***Rinsing.*** It is very important that the detergent has—amongst its other desirable properties that of being easily removed from the surface by rinsing water. At first it might appear that this is a trivial matter and that any water soluble substance will be easily removed in this way. Experience and experiment show this not to be the case, and it is now generally realised that there are considerable variations in the rinsibility of the common detergent alkalis.

It has been known for a very long time in a vague way that caustic soda is difficult to rinse from glass and other surfaces. This was evident from the fact that such a surface often showed a fine white film on drying after rinsing. If a film of detergent deposit remains after the rinsing operation, it may contain emulsified residues of the detergency stage and these may well contain bacteria and other matter.

The whole subject of rinsing has a special significance in relation to the machine washing of milk bottles or churns. Until recently, no very accurate data had been collected on this property of rinsability; earlier workers having used a titration method which permitted errors that in general invalidated the figures obtained. Recently, however, Liddiard and Harwood investigated the rinsing of alkalis and other detergents from glass surfaces using a conductivity method which did not rely upon the titration of alkaline residues. These workers found that the following detergent alkalis could be placed in this order for excellence of rinsing. The best was: (1) liquid silicate ($Na_2O : SiO_2$ ratio of 1 : 3·3); (2) liquid silicate ($Na_2O : SiO_2$ ratio of 1 : 2); (3) trisodium phosphate; (4) sodium carbonate; (5) sodium metasilicate; (6) disodium phosphate; (7) sodium orthosilicate; (8) caustic soda. They also conducted a series of experiments by adding 1 per cent. of various alkalis to caustic soda to see which would best improve its rinsing properties. These experiments revealed that the addition of 1 per cent. of sodium hexametaphosphate to caustic soda improved the rinsing qualities of that alkali to a very considerable extent. For this reason, sodium hexametaphosphate must be considered as having a dual purpose in detergency. It is well known for its advertised property of the removal of calcium and bivalent ions (water softening) and to this can now be added the very valuable property of improving the rinsing qualities of a detergent. The rinsing experiments would not have been complete without some examination of organic detergents and the first of these to be considered was sodium oleate, a common soap. It was fully expected from practical experience that this substance would possess poor rinsing properties, and this was found to be the case. Also, it was found that when soap was added to caustic soda, it rendered the already poor rinsing qualities of that substance even worse. In opposition to this, the addition of 1 per cent. of an organic wetting agent of the sodium alkyl sulphate type vastly improved the rinsing of the caustic soda. The alkyl sulphate wetting agent class of substances are, in general, good rinsers and this, coupled with their wetting properties, should make them valuable in the dairy since they have little smell and will not tend to impart a soapy flavour to the milk, although in any case, their easy rinsability would militate against it. This class of substances is restricted in its use mainly because of expense. They could not be used, however, in jetting type washing machines owing to the ease with which they foam. Even with extremely low dilutions, it is possible to convert the whole of the detergent solution in a hydro-washing-machine into foam in less than half an hour. Most water solutions which foam readily usually have low surface tensions. The permanence or stability of the foam usually depends on other factors.

(5) ***Buffering.*** It is important for alkaline detergent solutions to maintain their high *p*H during the detergency process in order that the sterilising power of the preparation remains high. Additions of small amounts of acid to the detergent solution should not reduce the *p*H appreciably, and the extent to which this reduction is resisted by the detergent is often described as its buffering power. True buffering, in the sense that there is a continual replacement of ions of one sign to replace those which are being removed by neutralisation, is not found to any great extent in alkaline detergents, but caustic soda very successfully resists small additions of acid until nearly the whole of the caustic soda is neutralised, when the drop in *p*H is extremely rapid.

Other alkaline materials, such as sodium metasilicate and sodium carbonate, begin to loose their high *p*H at an earlier stage than does caustic soda, but the drop is not so rapid. A more precise term for this phenomenon would be resistance to lowering of *p*H.

(6) ***Sterilising power.*** A good deal has been done on this point, as far as caustic soda itself is concerned, by Toulouse and Levine, and Buchanan and Levine in the United States; by Mattick and Hoy, Mattick and Sharpe, Hobbs and Wilson, and other workers in this country. It is generally agreed that there is a relationship between the time of contact, the temperature, and the concentration of the detergent which is such that, if one is held constant the other two vary inversely as one another, that is to say, that if the temperature is constant, and the concentration of alkali is reduced, the time of contact must be increased. As a result of this work, it has been generally insisted that for dairy detergency, as high a degree of caustic alkalinity is maintained as possible in addition to a high temperature, and these conditions are especially important for machine bottle washing. For plant and equipment, sterilising with steam or hypochlorites is usual, but should only follow thorough cleaning.

Types of Cleaning Operations. (1) ***Large vessels.*** In most cases, the materials required will be governed by the type of surface to be cleaned; thus, in the case of storage tanks, holder pasteurisers, and other large receptacles variation of detergent will be required for aluminium, tinned surfaces, and vitreous enamel. Aluminium requires either a detergent based on sodium carbonate inhibited with sodium metasilicate or detergent solutions based on low alkalinity silicates and wetting agents. Tinned surfaces may be cleaned with strongly alkaline detergents provided that where high caustic alkalinity is involved, a proportion of sodium sulphite not less than 25 per cent. is used in order to inhibit the attack on tin. Where detergents of low caustic alkalinity are concerned, the percentage of sodium sulphite necessary for inhibition may be reduced to 10 per cent. Liquid detergents based on the more siliceous silicates are particularly useful for tinned surfaces as well as aluminium. For vitreous enamelled surfaces, the best and safest detergent is a solution of alkyl sulphate wetting agent with no alkalinity present at all.

(2) ***Churns.*** The same remarks apply to aluminium and tinned churns as in section (1). Churns are recognised for their difficulty in cleaning and sterilising. Steam or hypochlorite sterilising should follow after efficient cleaning with a suitable detergent. Occasionally, churns are cleaned by a hot water rinse only. This means, that there is a considerable film of residual milk left behind. Steaming for the prescribed period may very well result in a near-sterile churn when the churn is rinsed for plating purposes within the hour prescribed by the Ministry of Agriculture. It must be pointed out, that there is still in the churn sufficient food to ensure rapid growth of the few residual bacteria, particularly during summer. Hence, when a fresh supply of milk is poured into the churn at the farm, the churn may not be in a fit condition to receive it. This should emphasise the importance of thorough cleaning before sterilisation whether by means of steam or hypochlorite.

The practice of washing tinned churns with strong alkalis containing no inhibitor is destructive and dangerous, since the corroded surface will ensure a most effective foothold for bacteria and will increase the difficulty of producing a near-sterile churn. Machine churn washers of various types are in use and all of them can use detergents suitable for the type of churn they are handling.

It is necessary to pay as much care and attention to the cleaning of the churn lids as to the churn itself.

Attempts have been made in the United States to utilise various kinds of acid detergents and acid injections to steam as a means of providing a sterile surface. Considerable success has been claimed for an injection of gluconic acid into hot water, or water and steam, as the corrosive powers of this material are markedly less than those encountered with many other acids. The use of such a method in this country has not, however, been developed, and the economics of the process may prevent its use because of the cost of gluconic acid.

There are several types of churn washers in existence, but nearly all follow the principle of a warm jetting pre-rinse followed by a hot jetting wash, and this, in turn, is followed by a hot rinse ; after this comes steaming while finally, a hot air blast is used for drying off the churn. It is important to ensure that the wash section contains a detergent suitable to the machine and the water, as well as being effective for the removal of the final adhesive film of fatty and milk residue which will, if not removed, eventually bring about an unsatisfactory condition of the churn as already mentioned. Nevertheless, in most machines, a great difficulty is encountered because usually the carry-over of detergent solution is so great, that, unless continual refreshers are made, the detergent solution becomes so dilute that it ceases to be effective.

An additional problem is created by the bottoms of the cans which hold an appreciable quantity of the solution, although some dairies drill holes in the bottom rim to allow the escape of the solution which would otherwise be trapped and carried forward.

It is possible to obtain detergents which are suitable for churn washers and which are adequately inhibited against the corrosion of the tinned surface. Aluminium churns are becoming more popular, and it may be that in a few years a considerable proportion of churns will be of this metal and its alloys. Should a dairy be handling mixed aluminium and tinned churns, it is essential that the detergent should be one which has no attack upon aluminium. Fortunately, detergents which have no attack upon aluminium will also be quite safe to use on the tinned surface, although high caustic alkalinity will not be present.

(3) ***Milk pipe lines.*** General remarks concerning metals and surfaces apply in this case also. The usual procedure is brushing and soaking in the detergent solution followed by soaking in a hypochlorite solution, boiling water, or steam. Angle bends require special attention as deposits are often heavier here, and corrosion is often found first in such places.

The pipe lines should be thoroughly flushed through with cold water before dismantling, and then they should be immersed in a fairly concentrated solution, say 3 per cent. of a detergent formulated so as to have no corrosive effect upon the metal. Pipe lines may be of stainless steel, tinned copper, tinned steel, or occasionally glass. Unquestionably, the glass pipe, although rather fragile, is most satisfactory from every point of view, but as a rule, gentle handling in the dairy is not often found, and metal pipes are usually preferred. Pipe lines which convey heated milk always present a more difficult problem. Occasionally they are cleaned by dilute solutions of phosphoric acid which may be done safely where the pipes consist only of stainless steel ; but for other metals or surfaces, except glass, this must be avoided, and the detergent should contain some proportion of polyphosphates to assist in the removal of the milkstone. The detergent for the soaking process should contain some proportion of wetting agent, and, after soaking, the use of the pipe brush should completely free the interior from all traces of milkstone and residue. The temperature of the soaking solution should be as high as possible, although very often, in practice, it rarely exceeds 140°. The sterilising of the pipe lines is best carried out by a solution of hypochlorite containing 200 parts per million of available chlorine ; this should be done after re-assembly, and shortly before the milk run commences.

(4) ***High temperature-short time pasteurising plants.*** These present the hardest cleaning problem in the modern dairy. In general, modern types are made exclusively of stainless steel and the customary procedure is for a circulation of an alkaline solution for about 20 min., to be followed by a flushing out of the plant, and, where necessary, a treatment with a weak solution of phosphoric acid to remove any calcium compounds which may show as a white film on the plate. More trouble as a rule is encountered in hard water areas than in soft. Wide variations in the difficulty encountered in cleaning these plants are often found to be due to the differing lengths of the milk run. The cleaning process should always be followed by opening of the plates and brushing down to ensure that perfect cleaning results. These plants can, with advantage, be finally sterilised by hypochlorite solution. This is sometimes left until shortly before the commencement of the next day's milk run. Work is proceeding on methods which will enable the cleaning process to be done in one operation.

Where the H.T.-S.T. plants are made wholly of stainless steel, it is possible effectively to clean them simply by the circulation of a very dilute solution of nitric acid. This practice is extensively carried out in Sweden where plants consisting totally of high quality stainless steel are to be found.

Some manufacturers of plate type H.T.-S.T. plants insists upon the use of an alkaline detergent on the plates before any acid solution, such as dilute phosphoric acid is used. This, of course, always refers to the stainless steel plate machine. The reason is that, if phosphoric acid is used first, this will liberate free hydrochloric acid *in situ* from chlorides in the milkstone residue, and this will initiate corrosion of the plate. However, if an alkaline solution is first used, the harmful chlorides are removed together of course, with most of the fatty material, and a given proportion of the casein, so that the removal of the final milkstone film by acid does not cause any corrosion. It may be that this difference is due to the fact that the alkaline treatment will remove approximately 95 per cent. of the milkstone deposit, and consequently, in the remaining 5 per cent. there will only be $\frac{1}{20}$ of the amount of chloride which was present in the original deposit.

The American practice for this type of machine has been in favour of an acid wash first, but in view of the observations of some British machine manufacturers, there would appear to be every reason to reverse the procedure. A convenient method of dealing with this cleaning problem as far as the plate type machines are concerned, is first to circulate a 1 or 2 per cent. solution of a suitable alkaline detergent containing a wetting agent, and after 15 min. or so to flush this straight out of the machine with cold water without opening the plates, then to close the machine and add a small amount of phosphoric acid to the water. Half per cent. of solution will usually be strong enough, and ¼ per cent. is sometimes used. The temperature of this solution is raised to about 120° and circulation continued for a further 10 or 15 min. when, again, the acid solution is flushed straight out of the machine with cold clean water. The machine should then be opened and the plates scrubbed down. Again, the final sterilisation is best carried out with a 200 parts per million solution of an approved hypochlorite, and this should be circulated immediately before the milk run commences.

Another type of H.T.-S.T. plant which is finding increased use, is one in which the milk flows over heated tubes by gravity in much the same way as a simple milk cooler, the milk being pumped to the top of the machine. This type of machine is fairly easily cleaned by the circulation of an alkaline detergent, again containing a wetting agent, with a final acid treatment when the condition of the heating section shows this to be necessary. Maintaining the detergent solution at an adequate temperature during the cleaning may not be easy since it is undesirable to apply heat to the heating section of the machine (as is done while the milk run is in progress) because this would tend to bake the milk residue further on to the surface in this section and would result in making the cleaning even more difficult. This may result in the temperature of the detergent solution being rapidly cooled as it comes down the heating section, and this of course means the loss of efficiency. Therefore, it is important that the temperature in the trough of this type of machine, when the detergent solution is there, should be as near boiling as possible. On the other hand, this type of machine has advantages in that the accessibility of the surface for cleaning enables the brushing to be quickly and efficiently carried out, while brushing of the outside sections can actually be done while the detergent is flowing down the machine. Sterilisation is again most conveniently carried out by means of a solution of sodium hypochlorite, and for this type of plant, spraying the hypochlorite solution on to the surface has been found to be quite effective.

(5) ***Bottles.*** These constitute probably the largest single item of cleaning in the dairy. A large number of machines are available for machine bottle washing. These consist of three main types: (*a*) machines operating wholly on the jetting or hydro principle; (*b*) machines operating partly on the jetting principle and partly on the soaking principle; (*c*) machines operating wholly on the soaking principle. A fourth class which, however, can hardly be described as a machine in the same sense as the previous examples, is the hand-operated device which provides agitation in a tank, and which is often used in combination with brushing and other manual methods. In the cases of (*a*), (*b*), and (*c*) it is advisable always to use detergents with a high caustic alkalinity. Temperatures for different machines vary, but the temperature factors, as already mentioned, are very important, and should be as high as possible. A temperature of 145° F. is satisfactory in order to impart to the highly alkaline solution a good degree of killing power against bacteria.

Class (a). These machines usually consist of a warm pre-rinse at about 90° F. and a detergent wash at about 140°, a warm circulating rinse at 90°, and a final cold mains rinse. The pre-rinse is often fed from the warm rinse tank, while this is maintained by a more or less continuous inflow of fresh water, or water from the mains rinse section. Some machines do not use a circulating warm rinse tank, but have a warm rinse which consists of mains water which is piped through the detergent tank, and is thus raised in temperature to a degree sufficient for the purpose. In such types of machines the detergent wash rarely exceeds 130°, and in all machines it is necessary to ensure that the bottle is not subjected to considerable changes of temperature as it passes from one section to another. These machines vary in their susceptibility to lubrication, and the amount of friction surface to which the conveyor is exposed determines the needs of the machine as far as lubricating qualities are concerned. The balancing of the detergent is very important in cases of difficult lubrication, and some of the most efficient cleaning constituents of detergent happen also to be bad for lubrication, but the reputable detergent manufacturer is well aware of these difficulties and will prescribe for every case. Different types of machines vary in their requirements, and also in the required strength of detergent. If the detergent section has a large number of jets, and the bottle consequently receives a larger volume of solution, then it is found possible to reduce the strength of the detergent very often to ¾ per cent., but where the jets are fewer, a higher concentration is necessary, and 1 to 1½ per cent. is usual. Although the strength of a detergent is often assessed on its caustic alkalinity (which, of course, would make caustic soda appear to be the best detergent) in actual fact, this can be very misleading. It may be that a high caustic alkalinity is desirable, as far as the destruction of bacteria is concerned, but it must be borne in mind that the bacteria are destroyed in the tank of the machine and not in the bottle, and it is important for the detergent to have very high cleaning powers in order to remove from the bottle all traces of residue. This has been achieved by blending the various detergent solutions carefully, and in this, caustic alkalinity is found to be a secondary consideration ; but bottle-washing detergents are, as a rule, sufficiently caustic to ensure proper destruction of the micro-organisms in the tank. In this connection, it is important that the solution should have as long a resting time as is practicable before being pumped again through the jets into the bottles so that the return of the solution to the tank should be as far away from the pump intake as can be arranged. Care should always be taken in charging the machine with the detergent as this passes rapidly into solution. Putting solid detergent straight into a tank without pre-mixing often results in a hard glass mass of the detergent forming on the bottom of the tank, and this will dissolve only very, very slowly. Where the detergent contains hexametaphosphate, this often tends to form a glass on the bottom of the tank and will hydrolyse owing to its slow rate of solution in this condition, so that the efficiency of the product for scale prevention may be lost. Most machines are provided with a grid on to which the detergent is placed while the pump is running, and the water, pouring over the grid dissolves the detergent, ensuring complete solution ; where this type of fitting is found, no mistake can be made. Otherwise, it is best to pre-dissolve a powdered detergent in some hot water in a bucket before adding to the tank.

Class (b). These machines rely upon the soaking principle very largely for the removing of the milk deposit, and in the detergent tanks of such machines, the detergent needs to be from 2 to 3 per cent. in strength, as a general rule. The detergent is also jetted into the bottle finally, after it leaves the solution in the detergent tank, thus ensuring that any loosely adhering particles are finally removed. The rinse tanks of such machines often also incorporate the jetting, although the final mains rinse is usually jetting only. Again, as in the case of class (a), the machines have a pre-rinsing section. Unquestionably, with this type of machine, the emphasis is on the soaking rather than on the jetting principle, and consequently it should be regarded, as far as the detergent is concerned, as a soaking type machine. But whereas the machines of class (c) (now very few), which operate wholly on the soaking principle can use detergents which contain wetting agents, class (b) are excluded from using this kind of detergent owing to the excessive foaming which would result, since the detergent solution is also jetted. The requirements in plants for soaking detergents are different from the needs of detergents which are made for jetting machines only, and it is important that this fact should be borne in mind.

Class (c). As mentioned above, there are not many machines in dairies now which operate wholly on the soaking principle, but where they are used, a good detergent, which contains a wetting agent, will often prove most efficient, while the very low surface tension of the alkaline solution will enhance the killing power of the solution against bacteria to a degree which far exceeds the results obtained with the higher surface tensions. Although, as has already been mentioned, a considerable amount of work has been done on the time, temperature and concentration relationships of caustic soda as a bactericide, the surface tension effect of compounded mixtures has not received adequate attention ; but the author has obtained results against the spores of *B. subtilis* in collaboration with another laboratory (unpublished) which shows quite clearly that the surface tension of alkaline solution is a factor of greater importance even than the temperature, and striking results were obtained with alkalis containing wetting agents. Where detergents containing wetting agents can be used, as in machines operating wholly on the soaking principle, lubrication is also greatly assisted while the correct choice of the wetting agent will also facilitate rinsability. Machines using soaking tanks are, of course, very much greater in size than jetting machines, but the total volume of the solution is often very much greater than that available in hydro machines when reckoned on a volume per bottle basis, so that the solution may have a much longer life but the capacity of such machines is very much greater, so that on balance the economics of the two systems are nearly equal. Considerable argument is still in progress as to the relative merits of jetting and soaking, but it is probably true to say that there is much to be said for both systems.

An important consideration in all kinds of detergency is the nature of the water. In particular, it is found that hard waters cause scaling of bottle-washing machines, with reduced efficiency, and the formation of a deposit which will harbour bacteria and prevent them from being destroyed by the alkaline solution. In order to overcome the trouble of the lime salts deposits, sodium hexametaphosphate has, for some time, been added to detergents for use in hard water areas. Those machines which incorporate a circulating warm rinse should be carefully watched so that this rinse water does not become contaminated and thus re-infect the clean bottles before they go to the final rinse. Sometimes this trouble is overcome by the addition of 50 parts per million available chlorine to the rinse water, but it is not a process which receives universal favour.

Graded and balanced detergents can be obtained for every condition of water and type of machine for use in bottle washing. The importance of such qualities as wetting and rinsability cannot be over emphasised where the speed of the bottle through the machine calls for the highest qualities from the detergent. Adequate lubrication for the machine has also to be considered and is usually imparted satisfactorily by detergents containing high caustic alkalinity.

(6) ***Floors and walls.*** Usually mild alkaline detergents which can be used with mopping and scrubbing are best and cheapest for this type of work and will be often satisfactory if followed by a thorough rinsing with clean cold water. Floors, however, are often attacked by soured milk residues and it is necessary that the solution should penetrate thoroughly into all crevices and porous portions of the floor. Hence, the incorporation of some soap or wetting agent is an additional advantage for this purpose.

Water. As previously observed, the importance of water in the dairy is very great. The primary consideration from the detergency point of view is hardness. Water up to 6 parts per 100,000 total hardness can be considered as satisfactory ; beyond that amount, progressively less so. Waters of up to 40 parts per 100,000 total hardness are often encountered in hard water districts. In such cases the water supply to a bottle-washing machine should be at least partially softened ;

if not completely, at any rate down to 10 to 12 degrees of hardness, and preferably down to 6. The quality of the water, from the bacteriological standpoint, is also important, as rinsing with contaminated water will undo the work previously carried out. Water from public water mains is invariably chlorinated and is satisfactory from this point of view, but large numbers of dairies have their own wells for their water supplies, and it is important that such sources should be examined at regular intervals in order to ensure that no contamination has taken place. Well waters are often found to vary in chemical content during a period of years and consequently, variations in hardness are found. Chalybeate (ferruginous or iron containing) waters obtained from wells often give considerable trouble in depositing ferric hydroxide with the liberation of active carbon dioxide which may be a cause of corrosion in machines and on metal surfaces. In mountainous districts, water may be quite soft and very often the *p*H is as low as 6, which means that the water is slightly acid and consequently will tend to be slightly corrosive. Such waters will be strongly corrosive if chlorine is added. Storage tanks for water in the dairy should be periodically inspected and where necessary disinfected. Final rinse water for all detergency processes should have a good bacteriological condition.

Chlorine. Several references have been made to the use of chlorine as a sterilising agent in this section on detergents, and so widespread has the use of chlorine become in the dairy that no section on detergency would be complete without a reference to this most valuable sterilising assistant.

The form in which chlorine may be best used is that of a solution of a soluble hypochlorite such as sodium hypochlorite, $NaOCl$. These solutions are marketed with an available chlorine content of about 10 or 11 per cent., and the Ministry of Agriculture and Fisheries has approved certain brands of sodium hypochlorite solutions for use in dairies.

To prevent the misuse of hypochlorite, 0·7 per cent. of sodium chlorate is added in order that the detection of hypochlorite in milk may be carried out where it is suspected that it has been added to the milk for the purpose of reducing the bacterial count. The *p*H of these hypochlorites, when diluted for use, should not exceed a *p*H of 9 and, in fact, the lower the *p*H of the hypochlorite solution which is being used, the more efficient will the bactericidal power be. This is shown by experiments which have been carried out from time to time, but it would appear that in actual practice, as distinct from laboratory work, the *p*H of the solution is not of such great importance. It cannot be emphasised too strongly that efficient cleaning must precede the use of hypochlorite, as organic material will take up the available chlorine and thus reduce the efficiency of the solution. The approved hypochlorites are all stabilised in order that they may keep without loss of available chlorine for a period in excess of 3 months. The time of contact needed for the hypochlorite solution in the plant which is being sterilised, should be longer than 5 min. In practice, periods of contact of 15 or 20 min. are quite common. Temperatures, of course, will have the effect of increasing the power of the hypochlorite because heat will have its own killing effect, and will render the micro-organisms more readily attacked by the hypochlorite solution. However, where there is a possibility of slight corrosive action on metals, then heat will facilitate this also.

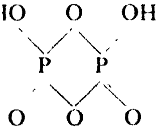
Aluminium is most readily attacked by hypochlorite solution while, as would be expected, stainless steel is most resistant. A tinned surface is also quite reasonably resistant to corrosive action. The manufacturers of these hypochlorites usually supply a simple chart showing the amount of the hypochlorite solution which must be added to a certain volume of water to produce a solution of the required strength, and these instructions should always be followed precisely. Again, in practice, the use of hypochlorite solutions is quite common on all surfaces in the dairy, except aluminium, but even this will be reasonably resistant when anodised.

Recent Developments. A very important development has been the incorporation of polyphosphates in detergents to prevent scale formation due to hard waters. Of these, sodium hexametaphosphate is the best known and most extensively used in this country.

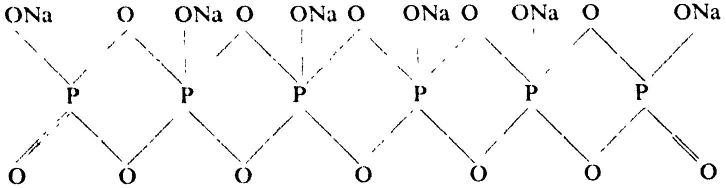
It should be mentioned, perhaps, that sodium hexametaphosphate is not the only phosphate of importance in water softening. It has long been known that trisodiumphosphate and tetrasodiumpyrophosphate have also considerable virtues in this direction. The polyphosphate $Na_5O_3O_{10}$ has sequestration powers similar to sodium hexametaphosphate and preparations of this containing sodium metaphosphate are sold in the United States similarly to the hexa-polymer. Sodium hexametaphosphate belongs to the group of polymerised metaphosphates, and this series has provided a considerable literature much of which, however, is confusing and contradictory. A number of metaphosphate salts have been investigated by various workers, *e.g.* Pascal's salt, which is a supposed monometaphosphate, sodium dimetaphosphate (fairly well established), Maddrell's salt, Knorre's salt (generally agreed to be trimetaphosphate), sodium tetrametaphosphate, and lastly, Graham's salt or sodium hexametaphosphate. A further compound, Kurrol's salt, has been claimed to be a higher polymer even than hexametaphosphate. This claim, however, is by no means substantiated. It has become clear that much of the literature is confusing because the workers concerned were not working with pure substances. One of the reasons for this is that the preparation of metaphosphates by the fusion of orthophosphate salts depends not only on the temperature of the melt but also on the rate of heating and cooling, different results being obtained by variations in these factors.

Behaviour of Metaphosphates. The work of Partridge, Hicks and Smith (*J. Am. Chem. Soc.*, 63, 454, 1941) gives a fairly good idea of the transformations which take place under changing conditions of temperature and heating rates. On heating NaH_2PO_4 below fusion, a metaphosphate is formed which corresponds to Maddrell's salt, another form of which occurs on heating to 425° C., then at about 500° C. this changes to another metaphosphate which is apparently Knorre's salt (trimetaphosphate). On heating the latter to 625° C. it melts, and when this melt is allowed to cool, Knorre's salt re-forms, but if it is quenched a glass without ordered structure is produced ; this is Graham's salt or sodium hexametaphosphate as we know it.

Yost and Russell (*Systematic Inorganic Chemistry of Fifth and Sixth Group Non-metallic Elements* (1944), p. 213) have suggested that



is the most satisfactory structural formula for dimetaphosphoric acid, and on this assumption, the structure of sodium hexametaphosphate might be :



There is nothing in such a formula to suggest why the hexametaphosphate molecule should be more unstable than that of the trimetaphosphate or other lower polymers, although the work of Germain (*vide infra*) suggests this.

It should also be mentioned here that there are some doubts as to whether Graham's salt is a single chemical entity. Work in The Svedberg's School at Uppsala has shown that a technically pure sodium hexametaphosphate contained 26 per cent. of a highly polymerised substance which could be brought down by ultracentrifuging (Lamm and Malmgren (1940), *Z. anorganischen Chem.*, p. 256, 103). There is little room to wonder at the confusion in the metaphosphate literature when the possibilities which this result entails are considered.

Hydrolysis of Hexametaphosphate. The practical use of sodium hexametaphosphate was based on the original water-softening work, and it is important from the point of view of detergency to consider the ultimate fate of sodium hexametaphosphate in hot alkaline solutions, and how long the water-softening properties can persist under these conditions. A few attempts have been made to determine the rate of hydrolysis of $Na_6P_6\ O_{18}$ solutions, and the most important of these will be mentioned. The statement in an official publication that sodium hexametaphosphate decomposes in aqueous solution at a rate which varies directly as the temperature and inversely as the *p*H, would seem to be based on the work of Germain (*Chimie et Industrie* (1936), 35, 22-6), but if so, since the highest *p*H mentioned in this work is 8·4, this evidently does not cover the significant *p*H range for alkaline detergents, and so cannot be admitted for our purpose as a satisfactory statement. The most significant observation made by Germain is that sodium hexametaphosphate hydrolyses according to two mechanisms which appear to be independent of one another. These are: (1) hydrolysis leading to NaH_2PO_4, probably with the intermediate formation of pyrophosphate, and (2) depolymerisation into one or more metaphosphates of undetermined degree of polymerisation which do not protect alkaline earth salts against precipitation. This reaction does not seem to depend on *p*H to any considerable extent so that in alkaline solution it becomes preponderant.

The second mechanism is one which must affect the use of sodium hexametaphosphate in alkaline detergents, and Germain's results show that about two-thirds of the hexametaphosphate is hydrolysed in 3 hr. at 100 C. at *p*H 8·4, and that of this amount about 65 per cent. was converted to other metaphosphates. Even after 14 hr. Germain finds that roughly half of the hydrolysis products are metaphosphates, but whether the same holds true in alkaline solutions is not known. The fact remains that the breakdown of the complex precipitates the calcium salts, probably as insoluble calcium salts of lower metaphosphates, and these are probably amorphous and therefore non-scale-forming. They may be precipitated as a fine sludge or a colloidal suspension which is easily removed by rinsing or flushing out the tank (if a machine). The result is, therefore, similar to that which would be obtained if the sodium hexametaphosphate did not break up, *i.e.* the machine remains scale free.

Although the ability to form a soluble complex with calcium and magnesium ions may not last very long in alkaline solutions when hot, it will last sufficiently long gradually to bring about the removal of existing lime scale in machines which, in a hard-water district, have previously been operated on a non-phosphated detergent. The fresh detergent solution, depending on its hexametaphosphate content of course, will remove a little of the scale as soluble calcium hexametaphosphate; in due time, when the hexametaphosphate breaks down, owing to depolymerisation or hydrolysis, the resulting calcium salts will be precipitated in an amorphous and non-scaling form.

Developments in Chemical Disinfection. Chlorine, and the hypochlorites, have for many years been used as a means of final disinfection after the detergency process in the dairy industry. In this country the use of solutions of sodium hypochlorite was legalised during the war, and so useful have they proved themselves that it seems unlikely that this treatment will ever be withdrawn. Nevertheless, following developments on the other side of the Atlantic, interest has been shown in the possibility of compounds which have the total virtue of high killing power against bacteria, and at the same time are non-toxic and leave no unpleasant odour after their use. The quaternary ammonium compounds have advanced this particular trend, and in the United States solutions of the substance are often used for washing a final rinse in various operations of dairy plant ; a review of their general properties and a recent development in bottle-washing detergents which has been made by Resuggan and Davis (1947), DI, **13**, 443, may be of interest. It is extremely doubtful whether this type of compound will ever supersede hypochlorites in this country as a final rinsing solution because of differences in cost, but the use of special types of quaternary ammonium compounds for a particular job does appear to be practicable. Hitherto, the only type of quaternary used for disinfection purposes has consisted of a long fatty chain attached to a nitrogen atom which contains three minor substituents, and these cations have a marked tendency to produce stable foams in extremely low concentrations ; often 1 part in 70,000 parts of water will create a foam which will remain for many hours. The development discussed below has been the production of a non-foaming type of quaternary which enables this class of compound to be incorporated in detergents which are used in modern hydro-bottle-washing machines.

Surface-active quaternary nitrogen compounds have many uses in applied chemistry, and since cetyltriethylammonium bromide was prepared and the colloidal properties of its solutions studied in 1913, compounds have been used as cationic finishing agents in the textile industry, flotation agents in mineral separation, and in many other processes where the adsorption of a fatty cation or its presence at an interface is desirable.

The value of certain of these compounds as bactericides has been known for several years, but considerable advances in their applications have been made recently, mainly in the U.S.A. where, from limited medical applications, their use has been extended to many purposes in sanitation, cleansing, and sterilising problems in the food and catering industries.

The type of quaternary ammonium compound which has been found useful for this work generally consists of a hydrocarbon chain varying in length from 12 to 18 carbon atoms, attached to the positively charged polar group which may be derived from simple alkylamines or pyridines. Sometimes the straight hydrocarbon chain is replaced by composite groupings as in the American product commercially known as " Phemerol ", which is p-tertiary octylphenoxyethoxy ethyldimethylbenzylammonium chloride, or modified by the presence of a double bond as when the oleyl group is used.

Compounds of this class are strongly adsorbed on most solid surfaces, particularly metals and glass, and form insoluble precipitates with certain anions, *e.g.* soaps, and other anionic wetting agents, silicates, polyphosphates, and simple orthophosphates. Sometimes the observation of the precipitate thus formed is made difficult by the presence of micelles ; and evidence exists that cationic surface-active agents in micellar form can solubilise water insoluble dyestuffs in a manner similar to soap.

One of the main characteristics of cationic surface-active agents of the type so far used, has been the formation of stable foams very similar to those obtained with soaps and other anionic wetting agents. This property is actually desirable in some applications and in others presents no practical difficulties.

The cleaning of food containers of many types has, however, always presented an important problem in sterilisation, since bacteriological cleanliness is as important as physical cleanliness.

Mechanical development has brought about the large-scale cleaning of returnable food containers by washing machines which operate for the most part by means of spraying a strongly alkaline detergent solution into and on to the vessel or container to be cleaned. A typical and important example of this can be found in the washing of milk bottles. Although the strongly alkaline detergents used for this purpose are capable of destroying most of the bacteria which are washed out of the bottle, this effect does not persist beyond the detergent tank—which is supposed to be maintained at about 140° F., and the remainder of the machine tends to become infected with bacterial growth, which through the medium of circulating rinses often re-infects the bottles when they are in an otherwise apparently physically clean condition. This apparently simple matter is a cause of great trouble in dairies and other food production establishments and efforts have been made in many ways to solve the problem of providing a commercially sterile—or near sterile—container, particularly in the case of glass containers, such as bottles where the condition is at its worst because of temperature limitations in the washing system.

Consideration of the above facts leads naturally to the question as to whether a bottle-washing detergent could be compounded which did not contain caustic alkalis, depend on high temperatures, or contain any poisonous, harmful, oxidising, or odiferous substances (*e.g.* phenols, or heavy metal compounds) and which would, by carryover, prevent the growth of micro-organisms in the rinse tank and maintain the machine in a bacteriologically clean condition. It would be necessary also for a solution of the detergent to possess a low surface tension in order that wetting, penetration and emulsification would be facilitated.

A survey of possibilities indicated that a germicidal cationic detergent of the quaternary ammonium class could provide the active germicidal and wetting properties for such a detergent.

Unfortunately, the types of quaternary ammonium compounds hitherto available readily make stable foams, many even in dilutions lower than 1 : 70,000 and, as the washing machines in question are extremely sensitive to traces of foam-making compounds, attempts to use them were unsuccessful as the washing operations fail owing to excessive foam formation.

It was then found that if instead of one long paraffinic chain, two shorter chains (totalling approximately the same number of carbon atoms as the single chain) were used, a bactericidal quaternary ammonium compound was produced which at concentrations below 0·35 per cent. did not produce a stable foam and actually showed no greater tendency to foam formation than distilled water. The first of this type was *di-n-octyldimethyl ammonium bromide.*

The results obtained showed that the bottles which resulted from the use of this detergent approached sterility to a far greater degree than those which were washed in the ordinary strongly alkaline detergent, while swabs of the machine showed enormous reductions in bacterial counts, with the almost complete elimination of coliforms.

Some physical and chemical properties of common detergents are summarised in Tables D I to D III.

TABLE D I

THE PROPERTIES OF CERTAIN COMMON DETERGENT SUBSTANCES

	Caustic soda	*Sodium meta-silicate*	*Tri-sodium phosphate*	*Sodium car-bonate*	*Calgon*	*Sili-ceous sili-cates*	*Soaps*	*Synthetic organic wetting agents*
Caustic alkalinity .	+ + + +	+ + +	+ +	+ +	0	+	±	0
Wetting . .	+	+ +	+	+ +	+	+ + +	+ + + +	+ + + +

TABLE D I—(*contd*)

	Caustic soda	*Sodium metasilicate*	*Tri-sodium phosphate*	*Sodium carbonate*	*Calgon*	*Siliceous silicates*	*Soaps*	*Synthetic organic wetting agents*
Deflocculating and emulsifying power	++	+++	++	++	+++	+++	++++	++++
Rinsing	+	++	+++	++	++++	+++	+	+++
Water softening	0	+	++	+	++++	+++	0	+++
Sterilising power	+++	++	+++	++	0 ?	+	+++	++
Buffering (resistance to lowering of *p*H)	++++		++	+	0	+	0	0

TABLE D II

SURFACE-ACTIVE PROPERTIES OF ALKALIS AND OTHER COMPOUNDS

Material	*Concentration*	*Surface tension (dynes per cm)*	*Advancing angle of contact*
Tap water	—	70 87	105°
Na_3PO_4, $12H_2O$	1 %	63 49	94°
Sodium			
hexametaphosphate	1 %	68 97	104
cetyl sulphate	1 %	41 66	70
abeitate	1 %	32 06	26
oleate	1 %	29 11	20°
salt of sulphonated bicarboxylic acid	1 %	25 31	10
alkyl naphthalene sulphate	1 %	30 85	62

SURFACE-ACTIVE PROPERTIES OF ALKALINE SILICATE MIXTURES

Silicate mixtures Na_2O SiO_2 ratio	*Surface tension (dynes per cm)*	*Advancing angle of contact*
1 3 3	55 4	Less than 10
1 2 0	62 2	40 5°
1 1 5	63 35	53
1 1 0	64 41	54
1 0 6	65 15	54 5°
1 0 5	65 59	55 5°
1 0 2	66 20	58°
1 0 1	64 41	60°
1 0 0	66 63	65°

TABLE D III

ANALYTICAL DATA FROM SOME DAIRY DETERGENTS

Na_2O, SiO_2 and P_2O_5 contents

A. General purpose detergent (for hand washing of equipment)	Na_2O	22·7
	SiO_2	14·2
	P_2O_5	6·7
	Organic matter	8·4
B. Liquid plant cleaner	Na_2O	11·4
	SiO_2	22·3
	P_2O_5	4·0
	Organic matter	10·2
	H_2O	47·0
C. Bottle-washing detergent (hydro)	Na_2O	47·2
	SiO_2	10·1
	P_2O_5	9·4
D. Bottle-washing detergent (soaker)	Na_2O	44·7
	SiO_2	11·6
	P_2O_5	4·6
	Organic matter	5·2

See also Bottle-washing; Churn washing; Cleaning and sterilising; Quaternary ammonium compounds; Water.

Refs.: Niven (1950), *The fundamentals of detergency;* Moilliet and Collie (1951), *Surface activity;* Schwartz and Perry (1949), *Surface-active agents;* McCutcheon (1950), *Synthetic detergents*, N.Y.

DETERGENT CONCENTRATION, MEASUREMENT OF. The problems of estimating and controlling the strength of detergents is one of the most important in the dairy industry, as in practice plant and milk containers such as churns and bottles cannot be cleaned satisfactorily and rendered "near-sterile" without the application of an efficient detergent. Although detergents depend for their efficiency largely upon their alkalinity, other factors such as wetting ability are of considerable importance. Since a detergent is compounded of specific constituents which are mainly alkalis such as sodium hydroxide, sodium carbonate, trisodium phosphate, and the silicates, it is sufficient in practice to follow the deterioration or weakening of the detergent solution by estimations of the alkalinity. Although the latter is weakened by neutralisation with milk-protein and salts and carbon dioxide, the chief factor is the dilution effect due to the carry-over by the churns and bottles from one rinse to another. Thus it has been observed that after a churn washer has been in use for 1 to 2 hr. the detergent solution may actually become a weaker alkali than the hot rinse which succeeds it, due of course to the carry-over of the pre-rinse to the detergent tank, and of the detergent to the hot-rinse rank. It is sometimes found that operatives in the dairy industry are very casual on the question of control of detergent strength, and a simple and automatic method of ensuring that a detergent solution is maintained at a specified strength and temperature is one of the urgent needs of the dairy industry.

Methods of estimating detergent strength may be considered in three groups; titration methods (Mattick and Hoy (1937) *Bottle Washing and Bottle-washing Machines*); pH indicator methods; "meter" methods.

Titration Methods. These are the best known and are commonly used for estimating and comparing the strength of detergent solutions. The technique is very simple and the only possible point of controversy is the choice of indicator. Phenolphthalein is most commonly used, and we may assume that this estimates all the caustic soda and part of the carbonate, silicate, and phosphate. If methyl orange or some similar indicator changing at about *p*H 3·5 instead of 8·4 is used, it may be assumed that not only the caustic soda, but all the carbonate and two-thirds of the phosphate is included in the estimation. However, as we are only interested in the weakening of detergent solutions, from the initial *p*H value of about 12 down to 10 or 9, it is quite logical to use phenolphthalein, and further, this has the advantage of giving a sharp end-point. A standard method was adopted under the National Milk Testing and Advisory Scheme (Min. Agric. Fish., Form No. C184/T.P.Y.) and is still in general use.

***p*H Indicator Methods.** Some years ago the possibilities of using *p*H indicators as a simple spot test for detergent strength were investigated. The trouble with all indicators in the high alkalinity range of *p*H 11 to 13 is their instability. Of those tested quinizarin-6-sulphonic acid appeared to be the most satisfactory from all points of view. The change of colour with *p*H was found to be as follows:

*p*H	*Colour*
14	blue (fades)
13	blue
12	indigo blue
11	violet
9	purple pink

Even this indicator was unstable at *p*H 13 and the blue colour faded rapidly in N sodium hydroxide but persisted long enough to enable a colour comparison to be made. There is no reason why such a method should not be very useful as a quick simple test for checking detergent strength, as the indicator gives a good colour change over the range 9 to 13, which is the most important range for detergents. A new B.D.H. 1014 indicator is now available for this range of alkalinity, and a Tintometer disc is also available which permits fairly accurate *p*H estimation.

" Meter " Methods. These may be defined as methods which can record changes in detergent strength by a meter. They have the advantage of being automatic, independent of the human element, give information which is constantly available, and by the use of suitable relays can be made to operate a valve controlling the addition of concentrated detergent solution to the tank.

Variations in the strength of alkaline solutions can be followed either by *p*H or conductivity measurements. For the former, the ordinary glass electrode would be unsuitable on account of the high alkalinity and an antimony electrode would probably have to be used. The conductivity method is more robust and preliminary work has shown that the method is suitable for detergent solutions.

Calibration of Instrument. Owing to the nature and strength of alkalis employed for detergents, the change of conductivity with concentration is not linear and any instrument must, therefore, be calibrated for each detergent. The fundamental calibration is based on sodium hydroxide from ¼ to 2 per cent., the various strengths then being expressed as figures on a scale marked from 0 to 100. Each type of detergent will naturally require its own calibration. A calibration for the three most important detergent constituents, sodium hydroxide, sodium carbonate, and trisodium phosphate, is shown in Table DM I. It will be observed that for a given concentration sodium hydroxide gives the highest conductivity, sodium carbonate is next, while the phosphate has the lowest meter reading. This, of course, follows from the known dissociation behaviour of the three compounds, for at a strength of 4 per cent. (N) sodium hydroxide is 73 per cent. dissociated, while the *p*K values for carbonic acid are 6·5 and 10·4, and for phosphoric acid 2·0, 7·1, and 12·3. An interesting point that is at once evident from the calibration curves (Table DM I) is that the effect of concentration on the total ionic activity is greatest with the phosphate and least with sodium hydroxide. In other words, changes in concentration have less effect on the dissociation of the salts of the weak acids than on the pure alkali. From the point of view of the detergent meter this means that the instrument is less sensitive to changes in concentration of sodium hydroxide than it is to those of the salts. As under normal conditions detergents consist largely of silicates and carbonate, we may expect that in practice weakening of the detergent will have an appreciable effect on the meter reading. If the detergent, however, is largely sodium hydroxide the meter will be less sensitive to dilution of the detergent.

TABLE DM I

DATA FROM CALIBRATION CURVE: METER READINGS

	Concentration %			
	0·25	0·5	1·0	2·0
Sodium hydroxide	80	87	91	97
Sodium carbonate	47	63	76	84
Trisodium phosphate . . .	20	43	62·5	75

Detergent meters must be treated as delicate instruments, and the cells regularly cleaned and calibrated from time to time.

A typical instrument is illustrated in Fig. DM 1.

Ref.: Davis (1951), *FM*, **26**, 13, 53.

DEVONSHIRE CREAM. *See* Clotted cream.

DEXTROSE. An alternative name for glucose (p. 490).

DEXTROSE LITMUS MILK. *See* Media.

DIACETYL. This diketone $CH_3 . CO . CO . CH_3$ is the chief constituent of the aroma of butter, being produced from citric acid (p. 228) and from lactose by certain bacteria, particularly the heterofermentive streptococci (p. 576). *See also* Acetoin; Citric acid; Coliforms; Lactic acid bacteria; Voges-Proskauer reaction.

Refs.: Prescott and Dunn; Stephenson; Cox (1946), *JDR*, **14**, 28 (effect of pH).

DIALYSIS. If two solutions of different concentrations of a salt are separated by a permeable membrane it is found that salt will diffuse from the stronger to the weaker solution. The same phenomenon occurs if larger particles of colloidal size are present. For example, the extractives, salts and sugar in milk can pass through such a membrane leaving the proteins and fat behind. This process is known as *dialysis*.

DIARRHOEA. Formerly summer diarrhoea in children was associated with raw milk, being caused by certain bacteria which gained access to, and proliferated in, milk. The increase in pasteurisation and other public health measures has led to a marked decrease in this complaint. *See* Diseases, human; Food poisoning.

Refs.: Wilson; Wilson and Miles.

DIASTASE. An enzyme splitting starch into sugars. *See* Constituents; Enzymes.

DIFFUSION. The mixing of two or more materials by movement of the molecules.

DIGESTIBLE PROTEIN. *See* Feeding.

DIGESTIBILITY. A general term indicating the ease with which a foodstuff can be broken down and absorbed by the alimentary canal. The process is a complex one and involves mastication and emulsification, the breakdown of protein in the stomach and intestine, and the breakdown of fat and starches in the intestine. In practice, individuality and the day to day health of the individual are important factors for specific foods (*see* Allergy). Bulk and concentraton (or amount of water in the food) are also important factors and this is undoubtedly one reason why cheese is considered indigestible, because weight for weight it is one of the richest foods in fat and protein (p. 204). The richness of milks and their curd tensions are factors in the digestibility of milk by " weak stomachs ".

See Digestion in the ruminant; Enzymes; Feeding; Humanised milk; Infant foods; Nutritive value; Soft curd milk.

Ref.: Bacharach; Bacharach and Rendle; Drummond and Wilbraham.

DIGESTIBLE NUTRIENTS. *See* Feeding.

DIGESTION IN THE RUMINANT. The stomach of the ruminant is divided into four parts, the rumen, the reticulum, the omasum, and the abomasum (Fig. Di 1). The rumen and reticulum together form a fermentation vat into which food passes. The epithelium lining these organs is stratified and squamous (*i.e.* similar to skin) and the only secretion which passes into these compartments is the saliva. The opening of the oesophagus lies in the area separating the reticulum from the rumen and the opening from the reticulum which leads to the omasum is ventral to it. These openings are joined by a groove formed by muscular folds of the stomach wall.

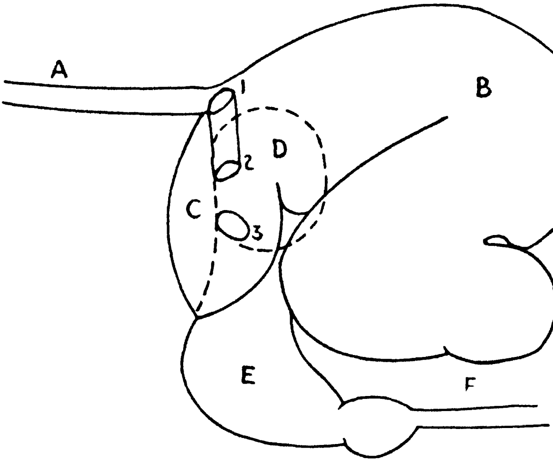


FIG. Di 1.—*The Stomach of the Cow.*

Organs outlined by a broken line are to the right of the rumen and reticulum. The two lines joining 1 and 2 are meant to represent the lips of the œsophageal groove.

A. *Oesophagus.* B. *Rumen.* C. *Reticulum.*
D. *Omasum.* E. *Abomasum.* F. *Duodenum.*

1. *Oesophageal opening.* 2. *Opening leading from reticulum to omasum.*
3. *Opening leading from omasum to abomasum.*

The omasum is spherical in the cow and is approximately the size of a small football. The interior is partially filled by laminae which project from the posterior curvature of the organ; these are of different sizes, some project nearly as far as the anterior wall and some only an inch or so. Intermediary sizes are present so that the whole interior is divided by these folds (Fig. Di 2). The epithelium is the same as that found in the rumen and reticulum. The omasum opens into the abomasum which is the only part of the stomach lined by glands. These glands are similar to those present in the stomach of man and secrete gastric juice.

The small and large intestines in the cow have no peculiarity beyond relative differences in length, capacity, and their attachments to the mesenteries.

Digestion in the stomach of the cow and other ruminants is radically different from gastric digestion as it is usually understood, for it consists of fermentation followed by peptic digestion. Digestion in the small intestine, as far as is known, is similar to that which occurs in other animals while digestion in the large intestine is much the same as it is in the horse and pig, but the extent to which it occurs is limited by: (*a*) the fact that the food has already been subjected to fermentation in the stomach, and (*b*) the capacity of the large gut which is smaller in comparison to the size of the animal than it is in the horse.

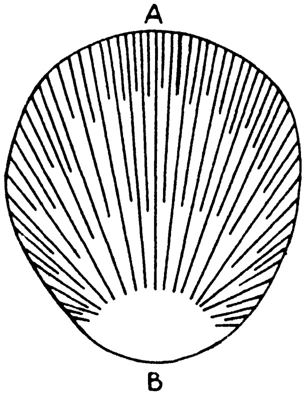


FIG. Di 2.—*Cross Section through the Omasum to show the arrangement of the Laminae Projecting into the Cavity of the Organ.*

A. *Posterior surface.* B. *Anterior surface.*

Digestion in the Calf. The stomach divides into four parts early in foetal life and at birth, it is an exact miniature of the adult organ except that the abomasum is relatively larger. Milk suckled by the calf passes straight from the oesophagus to the abomasum where it is digested in the normal way. The act of suckling produces a change in the groove leading from the oesophagus to the omasum; the folds forming the boundaries of the groove become tense, so that the groove is turned into a partially closed tube through which milk passes to the omasum. The orifice of this organ dilates and milk passes through the omasum to the abomasum. The same changes occur in calves that are fed from a bucket provided the animal understands that it is drinking milk. Even so, direct passage to the abomasum is not so complete and in some animals milk flows into the reticulum and rumen in large quantities where fermentative changes occur which may lead to indigestion.[1] A detailed study of the groove mechanism in lambs emphasises the importance of training if complete passage to the abomasum is to be obtained from bucket feeding.[2] Water passes to the reticulum and rumen.

Calves start to nibble food within the first week of life and within a month are eating substantial quantities. The age at which digestion in the rumen becomes important is not known, for any digestion that occurs there is the result of the activity of bacteria and other micro-organisms in that organ and there is no evidence to show when a normal flora is established.

Digestion in the Adult. (*a*) ***Mechanical aspects of digestion.*** Food and water pass into the reticulum and rumen, and the food is kept in motion by the movements of the muscular walls of these organs. The reticulum contracts briskly about once a minute and sends a wave of fluid backwards over the more solid mass of food in the rumen. The rumen next contracts first in the dorsal part and next in the ventral part so that the fluid is squeezed through the solid food and the mass is continually flushed. As the food becomes decimated movement of the mass increases when the walls of the rumen contract. Saliva is secreted continuously providing a constant flow of fluid to keep the contents moist, and the percentage of water present in the total digesta varies from 80 to 90 per cent. Regurgitation of semi-liquid digesta from the anterior region of the rumen and from the reticulum is brought about by an inspiratory effort of the cow when the glottis is closed so that no air can enter the trachea (windpipe). This effort produces a sudden fall in pressure in the thorax (chest) which dilates the oesophagus. Food therefore is aspirated into the oesophagus and from there is carried to the mouth by a wave of antiperistalsis.[3] Liquid is reswallowed at once but solid material is chewed for 40 to 60 seconds and when it is reswallowed it passes back again to the rumen.

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[1] Wise and Anderson (1939), *JDS*, **22**, 697.

[2] Watson (1944), *Council for Scientific and Industrial Research Bulletin*, No. 180.

Food flows from the reticulum to the omasum at regular intervals throughout the 24 hr. but little is known of the mechanism which regulates the flow. The volume of liquid flowing through the stomach is not known precisely. The volume of saliva secreted by the cow has been estimated to be 60 l. a day; if this is true, the volume of fluid passing from the reticulum to the omasum daily is considerable.

The omasum appears to act as a filter; solid food is always present spread in thin layers between the laminae, and its content of water is lower than it is in the rumen. It is not known whether loss of water is due to absorption from the larger surface area offered by the laminae or is due to contraction of the omasum so that fluid is squeezed from the solid food and passes to the abomasum. As far as is known, the oesophageal groove mechanism seldom, if ever, produces direct passage of food or water to the abomasum in the adult under normal circumstances.

Solid food may remain for anything from a few hours to 7 days in the rumen. Generally speaking, about half the solid has left this organ within 24 hr.; after this period the quantity leaving in subsequent 24 hr. periods progressively decreases as far as can be judged by the rate of disappearance of chopped stained straw from the rumen. Foods in a fine state of division such as meals and cakes leave more rapidly than roughage. Some may enter the reticulum and from there pass to the omasum without entering the rumen at all; this portion, however, does not represent a large percentage of the concentrated part of a ration.[4]

(*b*) ***Fermentation in the rumen.*** A prolific population of bacteria and protozoa inhabit the rumen. The protozoa do not appear to play an essential role in digestion, for lambs with no protozoa have been found to digest their food as well as those that harbour a normal population. Bacteria are the important organisms present and numerous species have been described. The principal results of bacterial digestion are that heat is liberated, gases are evolved, organic acids are formed and the bacteria population increases.

The heat liberated during fermentation represents a loss of energy from the food although by supplementing metabolic heat it may still be useful to the animal. The gases evolved are principally methane and carbon dioxide. Methane is a form in which energy is lost, for methane is excreted as a waste product. Carbon dioxide may arise from the food or from the saliva, for saliva contains large quantities of bicarbonate which neutralises the organic acids formed.

The acids produced are acetic, propionic, and butyric acids. The concentration present in the rumen varies with the diet and in direct relation to feeding and may be from 0·24 to 1·0 g. per 100 ml. of rumen liquor when expressed as acetic acid. Acetic forms from 65 to 70 per cent. of the total, propionic 20 to 25 per cent., and butyric acid 15 to 20 per cent. These acids are absorbed directly from the reticulum, rumen, and omasum, although some pass to the abomasum and small intestines. It has been estimated that a sufficient quantity of these acids may be produced to supply enough energy to account for over half the resting requirements of the cow.[5]

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[3] Dukes (1947), *The Physiology of the Domestic Animal*, 6th edit.

[4] McAnally and Phillipson (1944), *Biol. Rev.*, **19**, 41.

The food the cow eats provides the nourishment for the growth of the microbial population in the rumen. This means that all the complex molecules, *i.e.* proteins, vitamins and polysaccharides, etc., which constitute the bacterial or protozoan cell are synthesised in the rumen, but the extent to which the carbohydrate and protein of the food of the cow is converted into heat, gas, organic acids, and into bacteria and protozoa is not known. It is known, however, that cellulose, one of the most important carbohydrates of hay and straw, is digested only by bacteria and that 70 per cent. or more of this digestion occurs in the rumen ; in addition, proteins are utilised by bacteria in the rumen, and some nitrogen is lost in the process, for ammonia can be detected in the blood leaving the rumen : non-protein nitrogen also can be used by bacteria as a source of nitrogen and is thus incorporated into protein and its potential value to the animal is thereby enhanced. The value of first-class proteins in cows is less than it is in man and this may be due to (*a*) loss of some nitrogen as ammonia and (*b*) the value of bacterial protein may be less than that of the original protein. Finally, there is clear evidence that vitamins of the B complex are synthesised in the rumen by bacteria. This is a common property of many unicellular organisms and is a logical accompaniment of bacterial digestion.

The food that passes from the rumen to the abomasum and small intestine therefore includes bacteria and protozoa, the remainder the organic acids that have not been absorbed and also any food that has escaped bacterial attack. The proportions of these fractions have still to be decided. Protozoa are certainly digested, for the action of the gastric juice kills them and microscopic examination of the digesta leaving the abomasum shows that they are in various stages of disintegration. There is strong reason to suppose that at least some of the bacteria are digested in the small intestine, but direct evidence is still lacking. Any protein starch, or carbohydrates, other than cellulose or pentosans, etc., that escape fermentation in the rumen may be digested in the usual way in the small intestine as a result of the action of enzymes present in the pancreatic juice and the juices produced by the intestinal glands.

Fermentation commences again when food reaches the large intestine, but the extent of the overall changes is less. The same mixture of organic acids is, however, produced and absorbed.

Closure of the oesophageal groove is a vagal reflex elicited by stimulation of nerve endings in the posterior part of the mouth. Section of both of the vagal roots innervating the stomach of lambs abolishes the reflex closure of the groove. The propulsive movements of the reticulum and rumen are also abolished by vagal section, and rumination does not occur under these conditions. There is no doubt that the regular cycle of contraction which occurs in the reticulo-rumen sac is initiated in the brain—probably in the vagal nuclei of the medulla. Co-ordination of the various phases of rumination is, however, disturbed when lesions are made in the base of the brain anterior to the stalk of the pituitary body.

The appearance of protozoa and bacteria in the rumen of the calf that are characteristic of the adult population is influenced by contact between calves and adults. Calves kept in strict isolation do not develop a normal population in the rumen and do not thrive so well as calves inoculated with " cud " taken from adults.

Numerous types of bacteria have been isolated from the rumen of cattle and sheep. Many of these, and in particular those fermenting cellulose, are difficult to cultivate and are exacting in their requirements. Cellulose-fermenting bacteria from the rumen are strict anaerobes and the end products of fermentation, apart from carbon dioxide and hydrogen, are acetic and propionic acids. Some strains producing succinic acid have been reported. Mixed suspensions of rumen organisms, however, rapidly decarboxylate succinate to propionate and carbon dioxide, and the nutritive value of cellulose appears to lie in the acetic and propionic acid produced.

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[5] Baker, Harriss, Phillipson, McNaught, Smith, Kon, and Porter (1947-48), *Nutr. Abst. Rev.*, 17, 1-37.

When starch is fed in large quantities lactobacilli appear in large numbers in the rumen, lactic acid is formed in high concentrations and the contents become more acidic than is usual with other feeds. Under these conditions *Clostridium butyricum* has been found in the rumen of sheep.

Of the two principal types of protozoa present in the rumen—holotrich and oligotrich ciliates—the former ferment many soluble sugars and lay down in their cytoplasm a polysaccharide. When soluble carbohydrate is no longer available these organisms live on their stored polysaccharide, and the end products of their metabolism are short-chain fatty acids. Some of the oligotrich ciliates ingest cellulose particles and disintegration of cellulose occurs within their cell walls but it is not certain whether this is due to cellulolytic bacteria in the protozoa or to the protozoa itself producing a cellulase.

Considerable attention has been given to the degradation of protein in the rumen. Ammonia is formed in large quantities when ground-nut meal is fed to sheep and in smaller quantities when fish meal is given. The concentration of ammonia in the rumen bears a direct relationship to the quantity of urinary nitrogen excreted. Protein degradation also results in an increase in the concentrations in the rumen of isomers of butyric and valeric acids.

Absorption of short-chain fatty acids from the rumen is influenced by the concentration present and the *p*H. The lower the *p*H falls the greater becomes the quantity of free acid present, and the increase is greater as the hydrocarbon chain of the acids lengthens. Thus at a *p*H of 5·8 although N-butyric acid may form less than 20 per cent. of the total concentration of fatty acid in the rumen, in quantities absorbed it represents one-third of the total. Part of the butyric acid absorbed is metabolised in the rumen epithelium and converted to β-hydroxy and β-ketobutyric acids. Some propionate is also metabolised but losses of acetate are small.

Water is absorbed from the rumen and also from the omasum together with inorganic ions; chloride and inorganic phosphorus behave in an interesting manner for chloride is absorbed against a concentration gradient while losses of inorganic phosphorus are so small that they can only be measured by the use of an isotope even though the concentration in the rumen is ten times that of the plasma. As food passes through the omasum it loses bicarbonate and gains chloride in addition to losing fatty acid and water. The material entering the abomasum therefore is concentrated and with a low bicarbonate content which means that the cow is not embarrassed by the sudden liberation of carbon dioxide when the digesta enters the acid milieu of the abomasum.

In sheep the volume of material leaving the abomasum is of the order of 10 to 12 litres per 24 hours; half or more of this material is gastric juice. The events in the rumen and omasum, and the caecum and colon, are directly comparable as in both systems fermentation proceeds and is followed by dehydration; from the omasum, however, the partially dehydrated digesta passes on to be exposed to digestive juices in the abomasum and small intestine, while from the colon the digesta passes to the rectum and is excreted so that much of the valuable products of fermentation are lost as far as the animal is concerned.

A detailed account of the various processes of digestion in the ruminant can be obtained by reference to three recent reviews.[4, 5, 6] *See* Enzymes; Feeding.

[6] Owen (1947), *JDR*, **15**, 142-69.

DILUENTS, BACTERIOLOGICAL. For all normal purposes tap water (provided it is not too hard) makes an excellent and convenient diluent. Ringer solution may be inferior to tap water for the following reasons: (1) Distilled water from copper stills is very toxic for some types of organisms. (2) $NaHCO_3$, which is a constituent of Ringer solutions, decomposes on sterilisation, rendering the diluent more alkaline. Certain types, *e.g.* some lactobacilli, are very sensitive to alkalinity.

For media making, tap water should be employed. Not only is the use of distilled water an unnecessary expense, but metabolism experiments have shown that distilled water + salts is inferior to tap water + salts as far as activity is concerned. It is probable that this is due to the traces of minerals in the tap water.

One-quarter strength Ringer solution is commonly laid down in standard techniques.

Composition of Ringer Solution.

Sodium chloride . . .	9 g.
Potassium chloride . .	0·42 g.
Calcium chloride . . .	0·24 g.*
Sodium bicarbonate . .	0·2 g.
Distilled water . . .	1000 ml.

* Sometimes incorrectly given as 0·48 g.

Sterilise at 120° C. for 15 min. (Tap water may be used in place of distilled water.)

Ref.: Wilson *et al.*

DIPHTHEROIDS. A common term for *Corynebacterium* (p. 301) a genus of bacteria showing marked pleomorphism (variation in shape), granules and other irregularities. *See* Classification.

DIPLOCOCCUS. A term applied to cocci occurring in pairs. *See* Classification.

DIPPERS. Small cups with long handles for taking samples of milk. *See* Sampling.

DIRECT MICROSCOPIC COUNT. *See* Microscopic count.

DIRT, VISIBLE, IN MILK. This may consist of: (*a*) soil, sand, etc.; (*b*) dung, insoluble part of; (*c*) dust; (*d*) cinders, ash, etc.; (*e*) coal; (*f*) cellular tissue, hair, etc. Dirt in milk of itself has no effect on the keeping quality (*see* Sediment), but is aesthetically objectionable.

Milk is tested for visible dirt by the sediment test for routine purposes, and by the official S.P.A. centrifugal method for special purposes. For the former, ⅓ or ½ pint is usually forced through a sediment pad and the pad dried and compared with a set of standards prepared, *e.g.* from carborundum powder or other suitable material (*Min. Agr. Bull.* 46).

The Society for Analytical Chemistry considers that clean milk should have less than 1 part in 100,000 of moist dirt and that 2 parts represents a reasonable limit (1937, *A*, **62**, 287). *See* Bacteriological grading; Quality payment; Routine tests.

DIRTY CHURNS—EFFECT ON MILK. In the National Milk Testing and Advisory Scheme, a standard procedure was used for the examination of washed churns (Min. Agric. Fish, Form No. C168/TPY). Although it has been emphasised that the bacteriological standards prescribed are intended as a measure of efficiency of cleaning and sterilisation of churns and not as a measure of their effect on the keeping quality of milk placed in them (Min. Agric. Fish., Form No. C204/TPY), the latter question is of considerable practical importance.

In a series of trials by Davis, Lawes, Newland and Wilby (1945), *SAB*, p. 62, using raw milk of indifferent initial bacteriological quality placed in churns selected as being good or bad on visual examination, the degree of contamination

TABLE DC I

BRINE-COOLED PASTEURISED MILK HELD 10¼ HR. AT MILK TEMPERATURE 46-61° F.

		Rinse		Milk					
								C.O.B. (hr.)	
		Log. count (per ml.)	*Coli (per ml.)*	*Log. count (per ml.)*	*Coli (per ml.)*	*M.B. (hr. 37·5° C.)*	*M.B. (hr. 18° C.)*	*From filled churns*	*In 18° C. bath*
P. 1. Sterile bottle tested immediately		—	—	4·16	− 1	9	33½	41½	41½
P. 2. Sterile bottle		—	—	3·74	− 1	7	27	45	34¾
Churns	A.1 Mechanically washed and double steamed	0·78	− 1	4·23	− 1	8	27	44½	34¼
	A.2	1·04	− 1	4·06	− 1	7½	28	46½	36¼
	B.1 Mechanically washed	2·27	+ 1	4·11	− 1	8½	28	49½	39¼
	B.2	2·27	− 1	4·17	− 1	8½	28	50½	40¼
	C.1 Rinsed	7·30	+ 10^{-5}*	6·48	+ 10^{-5}	1½	3	26½	16¼
	C.2	8 05	+ 10^{-5}*	6·73	+ 10^{-4}	2	3½	26½	16¼
	D.1 Badly rinsed	8·90	+ 10^{-10}	6·90	+ 10^{-7}	½	1	23	12¾
	D.2	9·68	+ 10^{-7}	9·20	+ 10^{-11}	10 min.	1	21½	11¼
	E.1 Unwashed after " reject " milk	11·30	+ 10^{-4}	9·26	+ 10^{-2}	10 min.	½	17	6¾
	E.2	12 00	+ 10^{-6}	10 82	+ 10^{-8}	10 min.	10 min.	14½	4¼

*Highest dilution tested.

from churns, even those that were visually dirty, relative to the initial flora of the milk was so small that very little effect on the bacteriological quality of the milk was detected after a known time, during part of which the churns were taken for a lorry journey in order to simulate normal transport practice. No effect was detected with churn counts $< 500{,}000$, and even with a count of 5,000,000 the bacterial count of the milk was only very slightly affected. It required more serious contamination to produce an effect on keeping quality measured either by dye reduction tests or by increases in titratable acidity.

In a further series of experiments during June and July, some churns were deliberately contaminated so as to ensure churns ranging from " very good " to " very bad ". Estimates of the bacterial cleanliness of these churns and a study of milk placed in them has provided some answer to the practical problem of the likely effect on keeping quality of a given degree of churn contamination.

The results of a typical experiment are given in Table DC I.

The measurable effect on the deterioration of milk as shown by dye reduction tests and C.O.B. depends on the initial bacteriological quality of the milk itself, the contamination from the churns and the time of storage in the churns. Differences between milk stored in churns that were mechanically washed only or specially steamed after mechanical washing were in all cases insignificant. There is therefore no advantage in giving special treatment to churns which have been mechanically washed efficiently if they are to be filled immediately with milk. From the few figures available, it appears that the rinse count per ml. of churn capacity can approach that of the initial milk count, with little danger of serious deterioration of the milk placed in such churns. When the churn rinse count per ml. capacity markedly exceeds the initial milk count, there is considerable deterioration in the bacteriological quality of the milk. This is especially the case with good quality pasteurised milk. A still greater disparity between rinse and initial milk counts causes greatly increased deterioration.

DISEASES, HUMAN, SPREAD THROUGH MILK. Since 1857, when Dr. Taylor of Penrith demonstrated that an outbreak of typhoid fever was spread by milk, this food has been recognised as a vehicle of infection to man, and the amount of disease so spread has been shown to be very large. Broadly, the infection may be derived in two ways. One is from direct infection from the cow, since many of the diseases from which this animal can suffer also affect man. The other is by infection of the milk from outside during its passage from the cow to the consumer, for milk is both a much handled fluid and a suitable medium for the growth of many pathogenic bacteria, so multiplying greatly any chance infection. It is convenient to consider human infections from these two points of view, realising that some of them can be spread by both methods.

Human Diseases Associated with Infection of the Cow. ***Tuberculosis.*** This is by far the most important disease derived from the cow. Since its source is the bovine tubercle bacillus, it is important to consider in some detail the extent of tuberculosis in cows and the pathological foci most dangerous to man.

The only satisfactory measure of the extent of bovine tuberculosis is from testings of animals with tuberculin. Correctly carried out, this test gives a reliable estimate of the presence of tuberculosis, but does not measure the extent of the infection or the degree of infectivity. The results of abattoir findings have been used and broadly they correspond with tuberculin test findings, but are less reliable, as they are selective and include a high percentage of older animals and those of poor quality.

Unfortunately tuberculin testings have only been carried out with selected herds, usually in connection with the Attested Herd Scheme, or for the formation of herds to supply T.T. milk. This involves considerable selection, since herds anticipated to have a low incidence of tuberculosis are liable to preferential selection. This must be borne in mind. Nevertheless, the findings are of great value, and our only reliable source of information.

Official figures of the Ministry of Agriculture and Fisheries Attested Herds Scheme up to 31st December, 1953, shows that 4,154,134 cattle have qualified for the attested herds register. This represents 43·2 per cent. of the cattle in Great Britain, i.e. Scotland 64·7 per cent., Wales 64·9 per cent. and England 35·5 per cent. When the results are distributed into their counties they show very wide variations. Francis (1947) gives the percentage reaction for each county for *cattle* (not cows), using the survey figures for 1938. For English counties those with percentages under 10 include Cumberland (7·0), Devon (5·6), Durham (4·5), Yorkshire (7·2 to 9·3), Hereford (5·1). Over 30 per cent. positive were found in Cheshire (41·6), Derbyshire (32·2), Kent (37·0), Nottinghamshire (31·2). Wales counties ranged from 1·8 to 49·6 per cent., and Scotland counties from 2·6 to 66·3. These figures give percentages for England 14·1, Wales 4·1, Scotland 13·0.

These figures show that the incidence of tuberculosis in cows in Great Britain is very high, but varies markedly from county to county. The considerable number of herds free from tuberculosis naturally reduces the percentage of reactors, but as yet the proportion to the total cow population is too small to affect materially the overall figures. Allowing for the selective nature of these testings, a reliable figure today would be 35 per cent. of dairy cows affected with tuberculosis in Great Britain. This is a reasonable reduction on the 40 per cent. usually accepted for conditions existing a decade or so ago, and is due to the material progress being made in eradication.

While all " reactor " cows, *i.e.* those positive with tuberculin tests, are potential infectors spreading tuberculosis to other animals, their liability to be excretors of tubercle bacilli into the milk is very much lower. Tuberculosis of the udder undoubtedly is responsible for the heaviest infection of milk with tubercle bacilli. Savage (1929) discussed the incidence of this and concluded that most of the figures advanced were too high, and estimated clinically detectable udder tuberculosis as 0·2 to 0·3 per cent. in unselected herds, with a figure probably twice as high if we include all lesions demonstrable by pathological examination. This view obtains support from Torrance (1936) who, dealing with a cow population of 24,500, using biological tests, clinical examinations and post mortem pathological examinations, found udder tuberculosis 0·59 per cent. If we accept this figure with 35 per cent. of cows' tuberculosis, then 1·7 per cent. of reactors would suffer from udder tuberculosis. We must also accept, as Griffith and Griffith (1911) demonstrated to the Royal Commission on Tuberculosis, that tubercle bacilli may be excreted into milk by tuberculous cows without any udder lesion, but this is rare. We have also to realise that tubercle bacilli are excreted in dung, particularly from cows suffering from intestinal tuberculosis, and so may get into the milk supply.

The eradication of tuberculosis among bovines is outside the scope of this article, but it is worth recording that not only may cattle be infected with the avian type of tubercle bacillus, and so interfere with tuberculin tests in eradication schemes, but that human tubercle bacilli may occasionally be located in bovines and sensitise them to tuberculin. Practical experience shows that this may occur when persons suffering from respiratory tuberculosis are intimately concerned with the handling of cattle. Of greater significance to man is the fact that farm workers suffering from tuberculosis due to the bovine type may infect cattle and cause extensive disease amongst them.

Magnusson (1941) gives an interesting example from Sweden when in a herd of 74 cows which had shown no reactors for seven years, 49 reactors were suddenly found. Infection was traced to a woman milker found to be suffering from pulmonary tuberculosis due to the bovine bacillus.

The very varied incidence of tuberculosis in dairy cattle in different parts of the country is reflected in a wide range of findings of tubercle bacilli in ordinary milk from individual herds. Percentages ranging from 3 to 15 per cent., or even higher, are recorded. When bulked milk is examined the percentage is usually 80 to 100.

Since bacteriologists can differentiate the type of tubercle bacillus in individual human cases from which suitable material is obtainable, we are in a position to determine with considerable accuracy the proportion of human tuberculosis which is of bovine origin. This we can assign to milk, with some small share by milk products, since tuberculous meat infection is relatively negligible. Savage (1929), using the official statistics of deaths from each variety of tuberculosis, made this calculation in 1927. A special Tuberculosis Committee of the People's League of Health (1931) reinvestigated the problem in 1931, and produced very similar figures. Savage brought his figures up to date in his Mitchell Lecture (1933), and the following table is taken from that lecture (Table Ds I):

TABLE Ds I

Year 1931

Type of tuberculosis	*Deaths under 5 years*	*Percentage bovine*	*Calculated deaths of bovine origin*	*Deaths over 5 years*	*Percentage bovine*	*Calculated deaths of bovine origin*	*All ages calculated bovine deaths*
Respiratory .	303	0	0	29,355	1	294	294
Nervous . .	1286	34	437	1,312	20	262	699
Abdominal .	294	80	235	800	33	267	502
Generalised .	327	25	82	971	9	87	169
Other varieties .	55	20	11	1,115	5	56	67
All kinds . .	2265	33	765	33,553	2·9	966	1731

This and similar estimates have been accepted by all authorities, but it is important to consider how far they are reasonably accurate for 1952. On the one hand, tuberculosis as a whole has shown a steady decline apart from a temporary war increase. We do not know whether that small percentage due to the bovine bacillus has declined proportionately, but in view of the great increase in the pasteurisation of milk in our larger cities, it is reasonable to postulate some decline. On the other side, there is one considerable miscalculation in the above table suggested from recent data. This is the extent of bovine infections in pulmonary tuberculosis which is evidently higher than the 1 per cent. used in the table. Griffith and Munro (1944) have summarised the figures up to 1944, including their own work and that of Cumming, Lynn and Cutbill, Paget and others. These are briefly set out in the following table (Table Ds II):

TABLE Ds II

Country	*No. of cases investigated*	*Bovine T.B.*	*Percentage bovine*
Scotland	2769	160	5·7
England, Wales and Eire .	4194	81	1·9

The cases of bovine infection were distributed unequally in the different regions and, in general, with gradually decreasing frequency from the north of Scotland to the south of England. For calculation purposes a figure of at least 2 per cent. bovine bacilli in respiratory tuberculosis is reasonable. This would add 294 deaths to the above table and raise the total deaths to 2025. Probably the total annual deaths today are somewhere about 1500. In 1920 similar calculations as in the above table gave about 2600 calculated deaths a year.

Deaths are an end factor, and many subjects (bone and gland infections) do not die directly from the infection but are involved in prolonged suffering as the Report of the People's League of Health (1931) points out:

" In England and Wales about 6 per cent. of all deaths from tuberculosis are caused by the bovine type of bacillus. About 2000 deaths in England and Wales, mostly in children, occur annually from this source. At least 4000 fresh cases of bovine infection develop each year, an immense amount of suffering, invalidity and often permanent deformity, being thus caused by this bacillus."

Apart from indicating the greater incidence in Scotland over England, nothing has been written as to the regional distribution of the bovine cases. There is a large volume of evidence showing that the incidence is considerably higher in rural areas, particularly over recent years, when so large a proportion of the milk going to our cities is pasteurised. Space will only permit of two illustrations.

Blacklock (1947), making careful bacteriological and pathological examinations of children under 13 years infected with the tubercle bacillus, found the bovine percentages to be: primary lung lesions 3·6; abdominal 80·8 (for 1914-32) and 64·7 (1943-44); cervical glands, 70·2 (1914-32) and 67·5 (1943-44). Some distribution figures were (Table Ds III) :

TABLE Ds III

Area	*Tuberculosis meningitis % bovine*	*Surgical tuberculosis % bovine*	*Milk supply as regards heat treatment*
Glasgow	2·3	8·8	95 % heat treated
The large burghs in the Clyde valley	8·2	13·6	Considerable heat treatment, but much less than Glasgow
Rural areas in the western counties . . .	10·9	44·4	Practically no heat treatment

Cervical adenitis cases of bovine origin were 77·2 per cent. in country areas as compared with 46·8 per cent. in urban areas.

Price (1938) in Canada examined a series of 500 tuberculous children under 14 years of age over a period of 13 years. Of these, 9 per cent. of extra-pulmonary tuberculosis were of bovine type. None of the cases came from Toronto, a large city with 100 per cent. pasteurised milk. All these bovine infections came from Ontario outside Toronto, and the history invariably revealed that the child had been fed with raw milk. From 200 samples of pooled raw milk coming into the city to be pasteurised 26 per cent. yielded living tubercle bacilli.

Uudulant fever. In Great Britain this disease in man results from infection with *Brucella abortus*, the organism which causes contagious abortion in cows. Contagious abortion is widely prevalent in this country. Infection with other *Brucella* strains are frequent in other countries, but in Great Britain practically all the human cases are with this one type.

Undulant fever is not notifiable in Great Britain, and the exact number of cases which occur annually is not known. An estimate is possible from large scale agglutination testings of sera against *Br. abortus*, but these have not been carried out systematically, particularly in rural areas where a higher incidence may be anticipated. Of 3175 sera examined from various sources 101 were positive, giving a positive percentage of 3·18 which corresponds to 440 new cases a year (Topley and Wilson). In addition, there are many cases of latent infection, with positive serum agglutination below the significant figure of 1 : 80+, infections associated with the comparatively low pathogenicity of *Br. abortus* to man. G. S. Wilson's (1932) estimate of about 500 new cases annually is probably near the mark. The discrepancy between the high proportion of infections in cows and the relatively few cases of undulant fever is due partly to numerous minimal infections with no definite symptoms but causing resulting immunity, and partly to the low virulence of this organism to man.

Examinations of milk show that in Great Britain some 20 to 30 per cent. of herd milk samples contain living *Br. abortus* organisms, but the percentages vary widely in different areas. For example, Pullinger (1934) found 37 per cent. of mixed milk from single farms positive in Cheshire and only 19 per cent. positive in Somerset. Priestly (1934), using positive agglutination reactions as criteria, records variable figures, but not less than 20 per cent. of cows showed antibodies specific to *Br. abortus* in their blood.

Infection in man is usually due to the consumption of infected raw milk, but a considerable proportion is spread by direct contact with infected animals amongst farm workers, veterinary surgeons, etc.

The majority of recorded cases are single cases (Dalrymple-Champneys, 1933), but some outbreaks do occur. Small epidemics in schools have been recorded by Elkington, Wilson, Taylor and Fulton (1940), and by Cruickshank and Stevenson (1942).

Streptococcal infection. The most important outbreaks are associated with an infected cow, but some are due to direct infection of the milk after milking. For convenience both are considered here together. The diseases in man so spread are outbreaks of septic sore throat, scarlet fever, and a few other conditions very rarely, such as streptococcal food poisoning. Mastitis, acute or chronic, is one of the commonest affections of cows, and while several different organisms may be associated, by far the commonest is *Str. mastitidis* (also called *Str. agalactiae*). Savage (1906-9) (1911) proved that this organism was harmless to man by swabbing his throat with huge numbers recently isolated. He further showed that when a cow suffering from mastitis caused an epidemic of septic sore throat it was due to an invasion of the cow's udder by a streptococcus strain of *human* origin (*Str. pyogenes*), capable both of causing mastitis in the cow and sore throat outbreak through infection of the milk supply. This view, regarded with considerable scepticism at the time, has now been completely confirmed. These *Str. pyogenes* strains are haemolytic, and mostly fall into Group A of the Lancefield classification, but include several of Griffiths' types. As Allison showed in 1942 some 90 per cent. of pathogenic streptococci belong to Group A. The bovine types may or may not be haemolytic, and are usually Group B (Lancefield). These *Str. pyogenes* strains do not readily establish themselves in the bovine udder, and being derived from a milk handler, the combination of circumstances leading to a successful outbreak of mastitis of human origin is rare. In consequence, human outbreaks so originating are few in this country, but seem to be more frequent in America. They may, however, be very widespread, such as the extensive Hove-Brighton epidemic in 1929-30 with more than 1000 cases and over sixty deaths. Milk has been a frequent vehicle for the spread of scarlet fever, often causing extensive outbreaks. Until comparatively recently this was ascribed to direct infection of the milk from an infected milker or other person handling the milk. This method is probably responsible for many outbreaks, but a consideration of the whole of the evidence suggests that a majority is due to infection through the cow's udder, exactly as for septic sore throat outbreaks. Two fairly recent outbreaks are good examples. In the 1939 Elgin outbreak (Douglas *et al.*, 1942), there were over 214 cases all traced to one particular milk supply. The strain responsible was *Str. pyogenes*, Group A (Lancefield), Type 3 (Griffith), isolated both from cases and from a cow in the implicated herd who was excreting this organism from one quarter. In the 1936 Doncaster outbreak (Watson, 1937), there were 135 cases of scarlet fever and 229 of sore throat. The cases were spread over 11 days, and the source of infection was a cow with an indurated teat excreting the same *Str. pyogenes* Griffith Type 2.

Part of the evidence against direct contamination of the milk being a common method of introduction is the fact that *Str. pyogenes* grows with great difficulty and slowness in ordinary milk. This was shown by Jones (1928), and more recently by Pullinger and Kemp (1937).

In U.S.A. Dublin *et al.* (1943) record that in the 25-year period 1917-41 there were 57 outbreaks of scarlet fever and sore throat in the State of New York, excluding New York City. In the 9 recent outbreaks fully investigated, 5 were scarlet fever and 4 were mixed scarlet fever and sore throat, and with one exception all were due to an infected udder.

Food poisoning The types of food poisoning which may be spread by milk are staphylococcus food poisoning and that due to Salmonella organisms. Both may be associated with cow infections, but our present evidence is that staphylococcus outbreaks are mostly from direct contamination of the milk, while the Salmonella are mainly cow infections.

Staphylococcus food poisoning. Such outbreaks are associated with the presence of a special toxin, called enterotoxin, which is produced only by a small minority of staphylococcus strains. All are coagulase positive and mostly of the *aureus* type, but only a proportion of such strains produce enterotoxin and therefore can cause food poisoning.

Almost any food can serve as a vehicle, and milk is not a particularly common vehicle.

The common source of infection of the food is from a human carrier, but the possibility of staphylococci from the cow's udder being a source has been a good deal discussed. Staphylococci are fairly common in milk drawn direct from the udder, but the evidence that more than an exceptional strain can produce enterotoxin is very inconclusive. Minett (1938) isolated 38 strains of *Staph. aureus* from the bovine udder, 7 being from cows with acute mastitis, 8 chronic mastitis, and the rest from cows with normal udders. Enterotoxin was reported as demonstrated with 4, 5, and 7 strains respectively. This was based on the so-called kitten test, but results were negative, or very indefinite, when feeding experiments were carried out with human volunteers. Dolman (1941) (1943), who has done so much valuable work on this type of food poisoning, considers that endogenous infection of milk is an important source of infection. Out of 74 samples of raw milk examined he claims that 64 contained toxigenic staphylococci. The difficulty of accepting these findings is that the only really reliable test for an enterotoxin producing staphylococcus is human feeding tests and the reliability of the intraperitoneal kitten and other tests has been questioned and is doubtful.

When milk is infected with an enterotoxin producing strain there is abundant evidence that sufficient toxin to produce illness in men can result if the milk (or made up milk product) is kept for a number of hours at warm temperatures. This time-temperature interval is a very important factor in causing outbreaks. Indeed, the very first outbreak of this nature, reported by Barber (1914), was due to milk from an infected cow, and the fresh milk was harmless and only produced toxic effects after storage for 5 hr. at room temperature, which in the Philippines was about 28° C.

Salmonella food poisoning. Outbreaks of this type are not infrequent, either from the direct consumption of milk, or of its products such as ice cream. The writer some years ago had no difficulty in collecting over twenty milk-borne outbreaks due to *Salmonella.* They may be very extensive, and are explosive in character. For example, Newcastle-on-Tyne (1913), 523 cases, no deaths; Withnell and Chorley (1914), 317 cases, 2 deaths; Newcastle-under-Lyme (1914), 468 cases, 2 deaths; Glasgow (1914), 370 cases, no deaths; Aberdeen (1925), 497 cases, 1 death.

For most of these outbreaks the source of infection was a diseased cow. For instance, in the 1925 Aberdeen outbreak, infection was traced back to a cow with an indurated udder, which developed septicaemia, and *Sal. enteritidis* was isolated from udder and flesh.

The mortality in these milk-spread outbursts is conspicuously low. The isolation of *Sal. enteritis Dublin* from many recent outbreaks is the probable explanation, as it is of low virulence to man. This *Dublin* type is fairly common as a cause of diarrhoea and enteritis in calves and young cattle.

A typical outbreak from this type was the outbreak of gastro-enteritis affecting over 100 children (no deaths) in a Wiltshire school (Conybeare and Thornton, 1938), the vehicle being the school milk consumed raw. The *Dublin* strain was isolated from the patients, the milk and from the dung of one of the cows. The Knaresborough outbreak of 1944 (Sutherland and Bergers, 1944) with at least 162 cases, had exactly the same origin.

Diseases spread through direct infection of milk. Milk is a highly nutritious medium for most bacteria while it is a fluid exposed to much handling. Outbreaks due to contaminated raw milk are therefore fairly common. It is not possible to provide accurate figures since many outbreaks are never published, or only mentioned in local M.O.H. reports not readily accessible.

The Committee on Cattle Diseases (1934) in an appendix to their report, gave a list of milk-borne outbreaks reported between 1900 and 1931 in the United Kingdom and known to the Ministry of Health. The Committee remarks, " It cannot be regarded as exhaustive, for many epidemics, though recognised as being due to contaminated milk are not reported, and many slight outbreaks of common diseases due to milk are not recognised as such ". The list comprises: diphtheria 14 outbreaks; scarlet fever 28; scarlet fever and sore throat 1; enteric fever 30; typhoid fever and dysentery 4; paratyphoid fever 7; diarrhoea and sickness (?); gastro-enteritis 3; sore throat 4; Salmonella infection 3.

Undoubtedly this is a very incomplete list, and the author has notes of many outbreaks within these years not recorded in the series. The diseases spread by direct milk infection comprise the following:

(*a*) The enteric diseases. Typhoid fever, paratyphoid fever, dysentery.
(*b*) Other acute infectious diseases. Diphtheria, scarlet fever, sore throat outbreaks.
(*c*) Food poisoning outbreaks. Salmonella, staphylococcus and (very rarely) from particular streptococci.
(*d*) Gastro-enteritis of young children.

Enteric diseases. Typhoid fever is usually water-borne, but milk-spread outbreaks may result from the milk being infected from specifically contaminated water. Other outbreaks are due to direct infection of the milk by a typhoid carrier or a case of acute infection handling the milk. These outbreaks may be very extensive, such as the 1936 outbreak in Bournemouth and Poole, which affected at least 718 persons and caused about 70 deaths.

Improved methods of isolation of *B. typhosus*, and particularly new methods which divide the bacillus into types, have been able to demonstrate how wide may be the ramifications of milk-spread typhoid fever. Bradley (1943) supplies a particularly interesting illustration of 21 cases spread over 2 years (1941 and

1942), located in four different counties and with many distributors all traced to a typhoid carrier on a farm in Wiltshire 100 miles away who infected the farm milk. All the typhoid bacilli were of the para D4 type.

Paratyphoid is rarely water spread, but milk is a common vehicle. In a study of 40 outbreaks Savage (1942) records that 8 were milk spread, 2 ice cream, and 16 were from cream (real or artificial), or cream cakes. Here the source of infection is either a chronic carrier or a temporary carrier of *B. paratyphosus B.*

Over recent years there has been a considerable increase in the incidence of diarrhoeal diseases, including dysentery. A number of milk-spread outbreaks of dysentery has been recorded. If due to the more pathogenic strains, such as *Flexner* type, the mortality may be high, as in the Aberdeen outbreak of 1919, with over 1000 cases and 72 deaths. With a much less pathogenic type, such as *Sonne*, the mortality may be negligible. A good example is the outbreak in Chipping Wycombe in 1945, with over 76 cases and no deaths, due to milk being infected from a milker who was a carrier of the Sonne dysentery bacillus. The milk supply was T.T. milk.

Other acute infectious diseases. Scarlet fever and sore throat outbreak have already been considered, but are mentioned here as direct infection of the milk is one method of spread. Diphtheria outbreaks spread by milk are comparatively rare, but it is not difficult to collect many outbreaks and a number are never recorded. The mode of infection is from the handling of the milk by a person suffering from diphtheria, or one who is a diphtheria bacillus carrier. In an outbreak at Glastonbury, investigated by the writer in 1920, a diphtheria bacillus carrier who was a milker infected the milk supply, although he was recognised as a source of infection on the first day of the outbreak and was at once isolated. There were 58 cases directly spread by the infected milk and a further 51 spread from these by case to case infection, making a total of 109 cases directly or indirectly from milk. There were 15 deaths.

An interesting feature recorded in at least four outbreaks is the concurrent infection of sores on one or more teats of cows in the implicated herd and from which diphtheria bacilli have been isolated. These are important because they provide a persistent focus allowing continued re-infection of the milk.

Food poisoning outbreaks have already been considered.

Other milk-spread diseases. Anthrax is not uncommon in bovines, but is so rapidly fatal that spread through milk is a very unlikely contingency, and no outbreaks have been reported. Foot-and-mouth disease may be transmitted to man from infected cows and a number of cases have been reported, but it is not clear to what extent they are conveyed through infected milk.

Gastro-enteritis in young children. In the past, outbreaks of so-called " summer diarrhoea " were devastating and responsible for the deaths of very many infants and children under 2 yr. of age. There was much circumstantial evidence incriminating milk as one of the commonest vehicles of infection. The bacteriological findings have been diverse and various organisms have been suggested as responsible for particular outbreaks. No definite bacteriological connections have ever been established. At present there is a good deal of gastro-enteritis of unknown origin in infants. To some extent, with heavily infected milk, all bacteria of low pathogenicity may be in fact responsible.

The prevention of diseases spread through milk. This can be discussed only very briefly but a short statement may be helpful. It will be appreciated that the case against milk as a spreader of disease is a formidable one. On practical grounds it is convenient to discuss prevention under two headings, *i.e.* against bovine tuberculosis and the prevention of milk-spread diseases.

Tuberculosis. The only herds free from the risk of conveying tubercle bacilli in the milk are those completely freed from animals giving a positive reaction to tuberculin, and the only such herds are Attested and Tuberculin Tested milk herds. It is pointed out above that such herds are only a minority of the milking herds in the country. With the high incidence of bovine tuberculosis in Great Britain eradication progress must be slow. As a long term policy it is admirable and necessary in the interests of agriculture, but as regards public health it affects only a small part of the problem.

The suggestion that clinical inspections by veterinary surgeons can be an effective guard against the spread of tubercle bacilli in the milk has frequently been advocated, but scientifically it is unsound and against all experience. Its futility can be judged from the following comparative figures of milk from ordinary herds and Accredited herds (Table Ds IV). One condition of an Accredited milk licence is that every cow in the herd must be examined quarterly by a veterinary surgeon and all animals showing evidence of disease removed from the herd.

TABLE Ds IV

Areas	*Period years*	*Ungraded herds' milk % containing t.b.*	*Accredited herds' milk % containing t.b.*
Somerset	8 (1936-43)	3·0	5·5
Sheffield	8 (1935-42)	6·7	9·1
Leeds	10 (1933-42)	2·26	6·28
Manchester	7 (1936-42)	9·67	11·3
Bristol	7 (1936-42)	6·22	10·1
Liverpool	10 (1933-42)	9·07	4·2
London C.C.	7 (1936-42)	4·4-8·1	4·5-13·4

(In every year the percentage is higher for Accredited milk in London.)

Other diseases. Steps to ensure a clean milk supply are valuable on economic grounds, but clean milk is not safe milk, and there is very little connection between the two. The various diseases are spread by *specific* infection. Actually a number of severe outbreaks of infectious disease have been associated with milk with cleanliness of production well above the average. Measures to exclude possibly infectious persons from handling milk in any form are valuable, but mostly operate only after the risk has existed for some time and as a measure to prevent further spread. Medical supervision of milk workers is unlikely to prevent many outbreaks.

For all diseases, including tuberculosis, prevention does not lie along improved veterinary or medical examinations, or by studied efforts to produce a clean milk supply. The *only* satisfactory safeguard is to heat-treat the milk so that these possible specific bacteria are destroyed, a view accepted today by practically all scientific opinion, medical, veterinary and agricultural. Properly carried out (and with efficient control afterwards) all pathogenic organisms possibly present are destroyed, the nutritive qualities of the milk are not affected to any material degree, the taste is unimpaired and it is a practicable measure. The Government has now declared its policy of permitting only the sale of heat-treated or T. T. milk at some time in the near future.

The salient features of milk-borne diseases have been summarised by Wilson as in Table Ds V. *See* Diseases of dairy cattle; Food poisoning; Legal aspects.

Refs.: Barber (1914), *Phillipine J. Sc.*, **9**, Sec. B, 515; Blacklock (1947), *BMJ*, I, p. 707; Bradley (1943), *BMJ*, I, p. 438; Conybeare and Thornton (1938), *Min. Pub. Hlth. Rep.*, no. 82; Cruickshank and Stevenson (1942), *BMJ*, I, p. 522; Dalrymple-Champneys (1933), *Proc. Roy. Soc. of Med.* Sec. Epidemiology, **26**, 1093; Dolman (1941), *Can. J. Pub. Hlth.*, **32**, 183; *ibid.* **34**, 97 and 205; Douglas,

TABLE Ds V

INDICATING THE MORE COMMON TYPES OF MILK-BORNE DISEASE OF BACTERIAL ORIGIN AND THE WAY IN WHICH THE MILK BECOMES INFECTED (Wilson)

Bacterium	*Infections*		*Mode of infection of the milk*
	Disease caused in animal	*Disease caused in man*	
Mycobacterium tuberculosis (bovine type)	Tuberculosis in cattle	Tuberculosis	Mainly from infected udder of the cow; occasional organisms may gain access from cow's faeces
Brucella abortus	Contagious abortion in cattle	Undulant fever (often atypical)	From infected udder of the cow
Streptococcus pyogenes	Very occasionally mastitis in the cow	Septic sore throat or scarlet fever	(1) From cough-spray of the milker or other person handling the milk. (2) from udder of the cow infected from a human source. Evidence suggests that large epidemics are mainly due to milk infected by the second route
Corynebacterium diphtheriae	Very occasionally found on ulcerated teats of cows	Diphtheria	(1) From the cough-spray of the milker or other person handling the milk. (2) From ulcerated teat of a cow infected from a human source. Evidence suggests that large epidemics are mainly due to milk infected by the second route
Bacterium enteritidis, Bact. typhi-murium and certain other members of Salmonella group	Enteritis and septicaemic diseases, especially in older cattle. Rodent typhoid in rats and mice	Acute gastro-enteritis (food poisoning)	(1) From faeces of infected cattle. (2) Occasionally from diseased udder of a cow. (3) Possibly from urine and faeces of rats and mice. (4) Possibly from fingers of a human case or carrier
Bact. enteritidis var: dublin	Enteritis, especially in calves (calf-diarrhoea)	Acute gastro-enteritis or paratyphoid-like fever	(1) From faeces of infected cattle. (2) Possibly from fingers of a human case or carrier
Bact. typhosum	Probably non-infective to cows	Typhoid fever	(1) From imperfectly cleansed fingers of typhoid case or carrier. (2) From contaminated water used for cleaning milk utensils or for watering the cows or for watering the milk

TABLE Ds V (*contd.*)

Bacterium	*Infections*		*Mode of infection of the milk*
	Disease caused in animal	*Disease caused in man*	
Bact. paratyphosum B.	Probably non-infective to cows	Paratyphoid fever	As with the typhoid bacillus
Bact. flexneri, Bact. sonnei, Bact. shigae, and certain other members of the dysentery group . .	Probably non-infective to cows	Dysentery, diarrhoea, or sometimes acute gastro-enteritis	As with the typhoid bacillus
Streptobacillus moniliformis . . .	May be identical with Actinobacillus actinoides, which gives rise to broncho-pneumonia in calves. Common nasal parasite of rats	Rat bite fever	Probably from lungs of cattle or nose of rats
	Intoxications		
Staphylococcus aureus and possibly certain other organisms . .	Mastitis in the cow	Acute gastro-enteritis (rapid onset) due to specific toxin formed in the milk before ingestion	(1) From infected udder of the cow. (2) From nose or fingers of human carriers
Various non-pathogenic organisms . . .	Usually none	Gastro-enteritis or diarrhoea due to non-specific toxic substances formed in the milk before ingestion	Any cause of bacteriologically dirty milk associated with a warm temperature favouring prodigious bacterial multiplication

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Reviews: Scott (1935), *JDR*, **6**, 103; (1937), *JDR*, **8**, 265; Smith (1939), *JDR*, **10**, 355; (1941), **12**, 227; (1946), *JDR*, **14**, 419; (1950), *JDR*, **17**, 91; (1953), *JDR*, **20**, 115.

General Refs.: Miller; Chalmers; Enock; Hammer; Harvey and Hill; Rogers; Wilson and Miles; Wilson.

DISEASES OF DAIRY CATTLE. The dairy cow suffers as much as any domesticated animal from disease, a result facilitated by two basic conditions. These are, firstly, the severity of the modern production programme in that a dairy cow is expected to produce a large yield of milk and a calf each year, and secondly, the cattle are normally kept in close proximity to each other, for example, in cow-sheds.

The first condition naturally means that the dairy cow cannot have much in reserve, and hence any factor such as impaired feeding or microbial infection can more readily set up ill-health. The second condition is important because the herding together of dairy cows, particularly in close atmospheres, favours the spread of infection from one cow to the other, either directly or indirectly *via* human agencies. It is not surprising, therefore, to learn that losses in milk, calves, and cows arising from diseases are high in dairy cattle.

If one looks at the world picture, the worst diseases of dairy cattle are the highly infectious epizootics, such as cattle plague (or rinderpest), bovine pleuro-pneumonia, and foot-and-mouth disease. These diseases are no longer endemic in Great Britain, although foot-and-mouth disease still occurs from time to time. These diseases have been stamped out from Great Britain by the application of a rigid slaughter policy, as it is far more economic to the farming community and the nation to eradicate these diseases in this way than to suffer the heavy mortality and loss of condition usually associated with them. Foot-and-mouth disease is the least mortal of these diseases, but it is so highly infectious, and the resultant immunity set up in recovered animals is so short, that it is still more economic to stamp out the disease than to treat it. Whilst treatment, which is fairly simple, is being carried out, the disease would be spread to many other herds in the district, and consequently the disease would be continuously maintained in the country, with really severe outbreaks every few years, probably accompanied by high mortality. Indeed, it would be difficult to maintain the intense dairy farming of Great Britain if these so-called "killing" diseases had not been eradicated.

The diseases which now cause greatest damage to dairy farmers are of a more insidious character. They include tuberculosis, mastitis, contagious bovine abortion, Johne's disease, infertility, parasitic diseases, and a number of nutritional or metabolic diseases. These diseases will be dealt with here, and reference to many other less important troubles of dairy cattle will be omitted.

Bovine Tuberculosis. ***Incidence of the disease.*** Bovine tuberculosis is common in the dairy herds of Great Britain. Taking the cattle population as a whole, various estimates are given of the average incidence of the disease. These estimates vary for the whole country from 40 per cent. down to 20 per cent. In individual herds the variation is from 90 per cent. down to 0 per cent. By and large, the incidence of tuberculosis in dairy cattle is higher than that of beef cattle. If we take the dairy herds of Great Britain alone, we shall not be far wrong in estimating the average incidence of tuberculosis to be about 35 per cent. The incidence of the disease also varies considerably from county to county, being heaviest in the Midlands and lowest in parts of Scotland, such as the Isle of Bute and Ayrshire, and in Carmarthenshire in South Wales.

It is commonly believed that the burden of milk production and calf bearing lowers the resistance of the dairy cow to tuberculosis, but there is no exact evidence to support this. The disease is spread largely by way of infected breath and other excreta of cows, and consequently it is more readily spread in the cow shed than out in the open field. The amount of disease in a herd naturally increases with the average age of the animals in that herd, another factor which leads to its greater spread within dairy, as opposed to beef, herds.

Many feel that not enough effort has been given to the eradication of this disease from Great Britain. Since 1924, there have been Government sponsored schemes aiming at the eradication of tuberculosis or the production of tubercle-free milk from individual herds. In 1934 an Attested Herd Scheme was started, which Scheme, after a fairly slow start, has latterly gained momentum, so that in 1949 there were 44,889 attested herds in Great Britain, comprising about 1,762,200 cattle, or about 19 per cent. of the total cattle population of Great Britain. This, of course, is not the total number of cattle free from tuberculosis, as there are many cattle in non-attested herds that are not affected with the disease. *See* Legal aspects.

Cause of disease. Tuberculosis is caused by a micro-organism belonging to the bacteria group (*see Classification*). It cannot, therefore, be seen with the naked eye, although it can be observed with the aid of a microscope. It can be grown on special media in the laboratory, and then the growth, consisting of millions of organisms, can be seen by the naked eye. There are three main types of tubercle bacilli known respectively as human, bovine, and avian types, because each type sets up the common form of tuberculosis in its own particular species. Human beings can, however, be infected with either human or bovine tubercle bacilli, and cattle can be infected with any one of the three types. So far as is known at present, tuberculosis in cattle is not commonly set up by the human tubercle bacillus, and although the avian type may be more common in cattle, it does not appear to set up any serious form of the disease.

The tubercle bacillus can be fairly easily destroyed by heat. A temperature of boiling water (*i.e.* 100° C.) kills it within a minute, but it takes 30 min. to destroy it at 60° C. Pasteurisation of milk depends for its effectiveness upon the killing of the organism at the lower temperature of pasteurisation (*see Pasteurisation*, p. 787). Another important point affecting the control of the disease is that the bacilli may live in cow dung and on the pastures for many months, especially during the winter. Exposure to direct sunlight or excessively dry conditions reduces its viability.

The disease is spread mainly by inhalation, sometimes direct from one cow to another, and at other times by infected droplets from the breath of a tubercular cow alighting on materials which form dusts that are subsequently inhaled by another cow. The disease can also be spread by ingestion of contaminated food or water. More rarely it is spread by reproduction processes ; by transmission during service, or by transmission from mother to calf through tuberculosis of the womb or tuberculosis of the udder and infected milk.

Symptoms of disease. Although tuberculosis can produce a number of symptoms in dairy cattle, normally these are not observed, as the disease is more commonly recognised in the early stages through the use of the tuberculin test. In the early stages of the disease there are no marked symptoms, and the general condition of the animal may be excellent. One of the first symptoms to be observed is generally a short intermittent cough which increases on exercise. Later, the animal loses condition, and there may be a slight nasal discharge. The cough will develop and the breathing will become frequent and shallow. If left unattended, the disease may pass from a tubercular bronchitis to pneumonia and pleurisy, with the usual signs associated with these conditions. Gradual wasting will occur, and the animal will become what is commonly called a "screw". The condition may give rise to acute pneumonia, resulting in fairly quick collapse and death.

Abdominal tuberculosis is often a sequel to pulmonary tuberculosis, probably arising from the patient swallowing infected material which is brought to its mouth by a cough. Emaciation and loss of condition will generally occur early, and will be accompanied by other symptoms such as pendulous abdomen, " staring " coat, and often diarrhoea. Other forms of tuberculosis affect the womb and the genital glands, but the most important is tubercular mastitis. In this the udder gradually becomes hardened, commencing usually in one quarter and later spreading throughout the udder. The affected quarter or quarters normally increase in size, although the udder often does not appear to be painful. Subsequently, the milk, which is usually unaltered at first, becomes affected and appears thin and watery. The tubercle bacilli are then usually present in the milk, but cannot always be readily demonstrated microscopically, and consequently suspected milk is usually submitted to a guinea pig test. About 1 to 2 per cent. of the cows which give positive reactions to the tuberculin test are said to have affected udders and to give infective milk.

A condition often called tuberculosis of the skin occurs in dairy cattle in the form of a string of hardened buds, particularly down the legs. It is doubtful whether this condition is really due to tubercle bacilli.

Lesions. Tuberculosis is liable to cause changes in any part of the body, and when generalised, all over the body. It can easily be noticed through the formation of distinct swellings which may be deposited in the substance of an organ or upon the various internal surfaces of the body. These little lumps or tubercles may occur discreetly or collected together forming grape-like masses, or abscess-like lesions. They may spread throughout the organ, *e.g.* the liver, gradually incapacitating it from its normal work. In man these little tubercular nodules may become encased in calcified deposits, and so be rendered harmless, but this process does not readily occur in cattle. Lesions are commonly found in the lymphatic glands leading to the distinct hardening and swelling of these organs, which can, in suitable sites, be felt during life.

Treatment is not normally attempted with tuberculous cows, partly because it appears to be a difficult condition to cure, and partly because of the danger an infected animal is to other cattle and to humans whilst the disease is active. Treatment normally, therefore, resolves itself into the prevention or control of the disease.

Control of bovine tuberculosis. Attempts have been made to control bovine tuberculosis by two main methods : firstly, by the eradication of all infected animals, and secondly, by vaccination of young calves in the hope that they will develop a resistance to the disease and remain uninfected throughout their life. The first method is the common one, as the second is still in a developmental stage. Sometimes the two methods are used jointly.

The eradication of a disease by removal of infected animals obviously depends for its success upon a reliable diagnosis of the disease. It is not difficult to diagnose tuberculosis in an advanced stage of development, but unfortunately, it is often a slowly developing disease, and so may be present for months or years without being detected clinically. Those animals in the early stages of tuberculosis can, however, be detected by a special biological test called a tuberculin test. The percentage accuracy of this test when properly applied and interpreted is over 90 per cent., and so the test can form a useful tool for the detection of infected animals.

Various modifications of the tests have been used in the past, but nowadays a skin test is used. In this a specially purified product, obtained from growing the causal organism under certain specified conditions, is injected into the substance of the skin of the animal. If the cow is infected with the disease, then there will be a reaction in the skin, which by its size and character can be interpreted as a positive reaction.

Unfortunately, cows which have harboured other germs somewhat allied to the bovine tubercle bacillus but not pathogenic, may also set up a reaction, and so as to minimise the possibility of interpreting such a positive reaction to the bovine tuberculin as an indication of tuberculosis infection, a second injection of tuberculin from avian tubercle bacilli is made at the same time a short distance from the first. A comparison of the two reactions enables the veterinary surgeon with his knowledge of the herd to decide if the cow is really tuberculous.

In advanced cases of tuberculosis a negative reaction to the test may be obtained, but this does not matter, as in these animals the diagnosis can be made on clinical grounds alone.

The details of the method adopted for the control of tuberculosis must depend to some extent upon the incidence of the disease. In those countries, such as the United States of America, where the incidence of the disease was as low as less than 10 per cent., eradication by slaughter of all animals giving a positive reaction to the tuberculin test was possible without unduly upsetting the dairy industry and the supplies of milk to the human population. In Great Britain, where the disease was prevalent to the extent of 40 per cent., such a method is unlikely to succeed without grievous disruption of supplies of milk to the consumer public. Consequently, it is necessary to adopt a scheme leading to total eradication by stages. The first stage is to ensure that all milk is made safe for the consuming public. This is rarely done first ; it consists in the passing of legislation to see that milk from herds which may contain affected cattle must be heat-treated.

The second stage comprises the reduction of the danger to the human consumer and to the neighbouring cattle by the enforced slaughter of all cases of advanced or " open " tuberculosis in dairy cattle. Under the Tuberculosis Order of 1938 farmers must report such cases to the Government veterinary surgeon. They are then removed from the herd and slaughtered, the farmer being paid reasonable compensation. This stage does little, in fact, to reduce the incidence of the disease, although the official figures of such cases show a fall from 19,910 in 1938 to 2831 in 1952. The probability is that this fall is, in part, due to the increase in the number of herds freed from tuberculosis arising from the third stage of nation-wide eradication.

The third stage comprises the reduction in the number of infected cattle by voluntary schemes containing inducements to farmers to eradicate tuberculosis from their own herds. The inducements are of two kinds ; firstly, direct assistance by way of free tests of the herd for tuberculosis, and secondly, indirect assistance by the giving of higher prices for milk from herds freed from tuberculosis. Formerly the incentives were applied more to the production of milk free from tubercle germs, but under the Tuberculosis (Attested Herds) Scheme the aim has rightly become the production of milk from tuberculosis-free cattle. This scheme made a slow start, but has gone ahead more rapidly since 1945. In the following table are set out figures for the number of cattle taken under the Tuberculosis Order and the number of Attested Herds in Great Britain since 1937.

Year	1938	1940	1942	1944	1945	1946
Cows slaughtered under T.B. order	19,910	15,501	13,480	11,747	9,633	8,266
Attested herds .	4,644	16,249	16,145	16,976	20,036	25,355

Year	1947	1948	1949	1950	1951	1952
Cows slaughtered under T.B. Order	6,545	6,320	5,813	5,296	3,771	2,831
Attested herds .	30,436	36,986	44,889	55,045	74,028	96,429

The fourth stage of eradication takes place when, through the application of voluntary schemes, the number of tubercular cows in the country or in certain defined areas has been reduced to such a level that complete eradication, at least in those areas, can be made compulsory. To do this, compensation must be paid to the farmer for the animals compulsorily removed. This stage has recently been reached in Great Britain with the introduction of an area scheme for compulsory eradication.

There are many other matters of detail which are important to the success of these eradication schemes, but these need not be fully described here. They include the conditions necessary for the sale of infected animals, the introduction of animals into tuberculosis-free herds, the transit of animals, and the running of the ordinary markets.

Finally, reference must be made to the method of disease control by preventive vaccination. In such a method killed organisms or germs of weakened virulence are usually injected into an animal with the object of producing immunity to or a resistance against the more virulent, disease-producing organism. In bovine tuberculosis the method that has been most used is to vaccinate calves with an attenuated organism called B.C.G., after the French scientists who first used it. This vaccination is being tried on a limited scale in Great Britain, and it may be that the method will be used jointly with the slaughter policy in the final stages of eradication of bovine tuberculosis.

In 1953 the number of cattle in attested herds was about 50 per cent. of the total cattle population of Great Britain.

Contagious Bovine Abortion. This disease is another infectious disease of dairy cattle caused by a bacterium, *Brucella abortus*. It is sometimes called Bang's disease, and among scientists " bovine brucellosis ". The organism usually gains entry into the body with the food or water, and it settles most commonly in the womb of the cow. Here, during calf bearing, it may interfere with foetal circulation and cause the death of the calf (foetus) and its subsequent abortion. Sometimes the calf may be born alive. If so, the afterbirth is usually retained.

The incidence of infection among British dairy cattle used to be in the neighbourhood of 40 per cent., but since 1944 a voluntary calf-hood vaccination scheme has been in operation which has probably reduced materially the incidence of the disease.

Not only does the disease result in abortion and the spread of infection by way of the aborted calf, foetal membranes and discharges, but it may result in permanent sterility if the infection of the womb goes untreated. A further undesirable sequel may be the passage of the causal organism into the milk, which may then cause undulant fever in man.

The disease can be brought under control either by its eradication from herds or by vaccination. Formerly the eradication method was favoured because the available vaccines used to be composed of either fully virulent organisms or dead ones. In the former case, there was the danger of spread of the disease ; in the latter case, the immunity produced was very slight. Consequently, the eradication scheme was favoured in which infected animals were detected by a special test made on their blood ; they were then eliminated from the herd. The eradication method was not generally successful, however, owing to the widespread infection of dairy cattle, and the difficulty of maintaining the many rigorous conditions of isolation and of being a self-contained herd, which were imposed upon the freed herd.

When it was discovered that a suitable vaccine could be prepared from a weakened or attenuated strain of *Br. abortus*, called Strain 19, an official calfhood vaccination scheme was introduced. This enables dairy farmers to have vaccinated at reduced cost their calves over four months old and their maiden heifers up to the time of their first service. Adult cows can be similarly vaccinated when they are not in calf, but this vaccination does not come under the official scheme. It is still uncertain for how long the immunity lasts, and so many farmers repeat the vaccination after each calving. In the five years 1945, 1946, 1947, 1948 and 1949, the total number of calves and maiden heifers vaccinated under the scheme was respectively 205,871 ; 273,916 ; 239,985 ; 302,538 ; and 312,986. At the end of 1949 the total number of herds in the scheme in Great Britain was 70,248.

Mastitis. Mastitis, or inflammation of the mammae or udder, is one of the most serious diseases of dairy cattle. It causes great loss of milk, but this loss has been reduced considerably in recent years through the application of more effective curative measures.

In reality, mastitis is a term covering several diseases, each of which is caused by its own specific micro-organism. The common form of mastitis is called streptococcal mastitis, and is caused by *Streptococcus agalactiae*. Staphylococcal mastitis is caused by organisms of the staphylococcal group, and a third form of the disease is caused by *Corynebacterium pyogenes*. Another form of mastitis—tubercular mastitis—may be set up by tubercle bacilli. In Great Britain the commonest form of mastitis is that produced by infection with *Strep. agalactiae*.

It is thought that in any one year, about 25 per cent. of milking cows suffer for a longer or shorter time from some form of mastitis.

The disease is mainly spread from infected cows either directly by human hands, udder swabs, milking machines, or flies, or indirectly by means of infected milk, utensils, bedding, etc.

The disease may lead to changes in the udder varying from slight increase in density to distinct hardening, from no change in udder size or temperature to considerable swelling and local heat, from little change in the character of the milk to changes varying from the production of small flecks or clots to thick, purulent discharges, and from no change in general health to intense illness and death. Sometimes, the disease is protracted, but at other times it takes a short, rapid course.

The prevention of mastitis. This is best accomplished by the adoption of the strictest dairy hygiene during milking. Hands, udder cloths, and milking machines should not only be thoroughly cleaned, but they should be frequently sterilised or disinfected. It is best to have sufficient udder cloths previously sterilised to allow a fresh one to be used for each cow. Should a case of mastitis occur it is advisable to isolate her, or at least milk her last. Even in normal milking, it is an advantage to milk the heifers before the older cows. Care should be taken to avoid injury to the udder or teats ; if such injury does occur it should be treated at once.

Treatment. Early treatment materially reduces the severity of the infection in many instances, and hence the use of the strip cup or other means to detect early change in the character of the milk can be helpful. A bacterial examination of the milk from each cow in the herd will demonstrate the type of organism prevalent in the herd, a fact which can be helpful in deciding upon the type of early treatment.

Since the introduction of sulphonamides and penicillin, much streptococcal mastitis has been rapidly cured or shortened. By and large, penicillin is more effective than sulphonamides, and does not have any depressing systemic effects on the cow. It must be given in the correct quantities if it is to be fully effective. A proportion of the cases of streptococcal mastitis do not respond to penicillin but will to sulphonamides and *vice versa*, whilst a further proportion—about 10 per cent.—respond to neither drug. The introduction of penicillin in oil and of tubes containing single doses of penicillin suitable for direct injection into a quarter have reduced the possibility of spread of infection from one cow to another or from one quarter to another.

The treatment of other forms of mastitis is not nearly so effective, as sulphonamides and penicillin do not effect cures in a high proportion of cases of staphylococcal mastitis and fewer still of " summer mastitis " caused by *Corynebacterium pyogenes*. Sometimes the injection of an antiseptic emulsion into the teat canal or the use of a teat seal is effective in preventing " summer mastitis ". Before successful treatment can be established, much more research is necessary into these other forms of mastitis.

A cow with tubercular mastitis should not be treated, but must be declared under the Tuberculosis Order and slaughtered. *See also* Abnormal milk; Mastitis.

Infertility. Infertility is one of the major causes of loss in dairy cattle today. This may be due in part to the greatly increased productivity of the individual cow in the Nation's milking herd, this increased strain helping other exciting causes to become more effective. By and large, the causes of infertility can be sub-divided into two major groups: those which are due to specific organisms and those that arise from some physiological or feeding derangement.

Infertility due to particular organisms may arise from infection with *Brucella abortus*, *Corynebacterium pyogenes*, a virus, or protozoa called *Trichomonas foetus*, and *Vibrio foetus*. Other forms of sterility due to micro-organisms arise from mixed infections of the womb.

The major causes of sterility due to infection are due to *Br. abortus* and Trichomonas, each of which sets up an abortion, and when chronic may produce permanent sterility. As has already been pointed out, the losses from *Br. abortus* are being reduced by a process of calfhood vaccination. So far there is no specific treatment for Trichomonas infections, although the infected cows usually respond to local treatment. It is extremely difficult, however, to be certain of effecting a cure with an infected bull. It is usually necessary to discard such a bull. It would appear that infection with this micro-organism is on the increase in this country, although the growing popularity of artificial insemination in dairy herds is one means of helping to combat it. The practice also helps to control the spread of *Vibrio foetus*.

Infection of cows with Corynebacteria produces a disease condition of the female closely resembling that set up by Trichomonas. Early abortion usually takes place between the third and fifth months. The associated discharge is thick and yellow in colour, and has a foetid odour. Recently infected cows can usually be cured, but chronic cases do not respond well.

One form of inflammation of the vagina, known as " bull burn ", is thought to be due to a filterable virus. The condition is transmitted by the bull, which is also infected. Other forms of vaginitis may be due to a variety of organisms.

In all cases of infertility arising from infection, the treatment must be applied to the herd as a whole. Care must be taken to use the bull only on uninfected cows, or if the bull itself is infected, to discontinue its use.

Sterility arising from physiological derangement can be due to a variety of causes, although it is by no means clear what are the specific factors involved. Infertility may be associated with irregularity of the oestral cycle which, in its turn, may be due to pathological changes in the ovaries of the cow. The precise cause of these changes is unknown, and many suggestions have been put forward incriminating one or other of the several ductless glands of the cow. Sometimes the trouble is thought to arise from imperfect diet, such as in the condition of anoestrus or complete cessation of oestrus which, not infrequently, occurs during the winter months and which is thought to arise in part from the absence from the food of fresh young grass and/or sun-light. It is also still open to question whether some forms of infertility arise from a deficiency in this or that vitamin. Indeed, the whole question of diet and infertility requires much further research, particularly in view of the great increase in infertility of unknown origin which has occurred latterly in the dairy cattle of the country. There is no doubt that much infertility can be avoided if the veterinary surgeon is regularly consulted on breeding questions, diagnosis of pregnancy, and difficult birth.

Johne's Disease. Johne's disease is another bacterial disease, being due to an organism in some ways resembling that of tuberculosis and called *M. paratuberculosis*. The organism is found mainly in the lining of the intestine, where it may set up corrugations in the gut wall. The main symptoms are an intermittent but very weakening diarrhoea, often accompanied by rapid and progressive emaciation. All breeds of cattle are susceptible. Although the disease is said to be more common in certain areas, it would appear that it is becoming of more general and increasing importance. Affected animals excrete the germs of the disease with their dung, and thus contaminate the pastures. The method of disposal of affected animals has all too frequently, no doubt, facilitated the spread of the disease. In this method owners of affected animals have treated them in the hope of arresting the diarrhoea, when they are fed with the object of fattening them, and then they are sold on the open market. Infected animals have thus been spread widely through the markets. One of the most important facts recently discovered about Johne's disease is that the animal may be infected for very long periods before signs of the disease are shown. Animals under one year of age rarely show clinical signs of the disease, although it would seem that the infection is usually acquired in calfhood.

Prevention. There is no specific method of cure for Johne's disease, neither is there an entirely satisfactory diagnostic agent. A preparation made from the causal organism and called Johnin is sometimes used in the same way as tuberculin is used in the detection of tuberculosis. The accuracy of the Johnin test is not so high as that with tuberculin but it can be useful. Prevention is usually restricted to the following main lines. The removal of the major cause of spread of the disease, namely the clinically infected animals. These should be slaughtered and not sold with others to spread disease. The removal of infected animals should be accompanied by measures to reduce infection on the land by preventing cattle from obtaining water from drinking ponds, particularly those that have been fouled by infected animals. The cattle should be kept so far as possible off fields that have become previously infected. It is also highly important to remove calves from contact with infected cows immediately they are born and to rear the calves away from the adult animals until they are over a year old. Calves should not be put out to pasture on land previously used for adult cattle. In an infected herd, despite the fact that Johnin is not as efficacious as tuberculin, its use can be very helpful in detecting infected animals before they become clinically obvious and spread the disease.

Parasitic Diseases of Dairy Cattle. Several types of parasitic disease occur in dairy cattle, including those due to worms, to protozoa, and to arthropods, such as ticks and insects. In addition, there are the parasitic diseases caused by fungi, for example, ringworm. Included in the worm diseases are parasitic gastro-enteritis, parasitic bronchitis, and fluke disease. The main protozoal diseases in this country are bovine coccidiosis and redwater. The chief arthropod troubles are lice infestation, scabies, tick infestation and ox warble flies.

Worm diseases. The chief worm diseases of cattle are parasitic gastro-enteritis, parasitic bronchitis or husk, and liver fluke disease. The first two diseases are caused by round worms, and the last by a flat worm.

Parasitic gastro-enteritis. This is due to a heavy infestation of round worms in the fourth stomach and/or in the anterior part of the small intestine. Several species of worm varying in length from one-sixth of an inch to one and a quarter inches may set up the trouble. That which causes the greatest trouble, called *Haemonchus contortus*, is the largest, and is a blood-sucking parasite commonly found in the fourth stomach. The other species rarely suck blood.

The main symptoms of the disease are those of progressive loss of condition, which may result in extreme emaciation, and in very severe cases, even death. Calves are most susceptible to the trouble, after which resistance increases with age until adult cattle rarely succumb to the trouble unless there is a very heavy infestation of worms accompanied by some weakening strain, such as calving, heavy lactation, or extremely poor feeding. Generally, the first signs exhibited by a young animal is that it stops growing, it then begins to lose weight, and may develop diarrhoea. The coat loses its bloom and the skin its elasticity. In the case of the blood-sucking worm the mucous membranes may be pallid and anaemic.

The spread of infection is mainly *via* the dung, which will contain large numbers of eggs. Under suitable conditions the eggs will change to larval forms on the pasture and within four to five days become infective. They then migrate into the herbage and if eaten may spread the infection.

The disease can usually be diagnosed after considering the history of the case, but it is desirable to confirm the preliminary diagnosis by making a count of the worm eggs in the faeces. Although the count will vary to some extent with the condition of the animal, it is generally considered that the presence of 800 to 1000 eggs per gramme of faeces is an indication of pathogenic infestation. As few as 400 eggs per g. is suspicious if found in yearlings or two-year-olds. As the infection is normally picked up at grass, it is rare to find only one cow affected.

Treatment. The best treatment is to prevent the trouble by reducing the infestation of the cattle and thereby lowering the contamination of the pastures. This can be helped by ensuring adequate feeding, avoidance of over-crowding, and the giving of suitable anthelmintic drugs to prevent excessive infection. The best drug to use is phenothiazine, although copper sulphate and nicotine sulphate or other drugs may be used. Whatever drug is used, its use is accompanied by some danger, and should be administered under the direction of the veterinary surgeon. Death may follow bad administration of the drug. With some drugs certain symptoms develop which may give rise to anxiety, for example, a red colouration of the urine following the giving of phenothiazine, and a swaying action, and possibly collapse following dosage with copper sulphate and nicotine sulphate. It is desirable to try out the worm treatment on one or two cows first before trying it throughout the herd. Several treatments are desirable spread over a period of weeks; in particular, calves and young cattle should be treated once or twice whilst at grass in the summer and autumn, and again just before being housed for the winter.

The treatment of pastures with lime or copper sulphate is desirable. Care should be taken to avoid both over-crowding of pastures and the putting of young stock on pastures already grazed by adults. The introduction of other stock unaffected by the particular worms, such as horses, will reduce the danger. In severe cases a badly infested pasture may be ploughed up and re-sown, but it is always desirable to harrow the old pasture first in order to expose the eggs in the dung to the action of the air and sun for a few days before ploughing.

Parasitic bronchitis, husk or hoose. The most troublesome and commonest worm disease of young cattle. Resistance increases with age, but adult cattle may become affected if their condition is lowered and the pastures are heavily infested. The trouble is caused by a round worm ingested *via* the mouth. It passes through the wall of the small intestine, gains access to the blood-stream, and finally settles in the lungs. The bronchitis is accompanied by a cough, and often by symptoms of pneumonia, due to the large number of worms in the lungs or to a super-imposed bacterial infection. The disease produces gradual weakening of the animal and growing emaciation, and is accompanied by other signs of loss of condition. The disease may drag on for four or five months before the animal dies or recovers.

Diagnosis. The presence of the cough excites suspicion of husk, particularly after the calves have been out at pasture. A cough amongst calves which have been housed all the time is more likely to be due to a bacterial infection. The adult worm may be found on mucous which is coughed up, or larvae may be found in the dung. The larvae are usually small, being one-tenth of an inch long, whilst the worm itself is comparatively large, measuring up to 3½ in. in length. Clumps of the worms may be found on post-mortem examination in the wind pipe. As with parasitic gastro-enteritis, disease conditions do not arise unless very large numbers of parasites are present.

The disease may be *controlled* by the removal of the animals from infected pastures, giving them supplementary rations if possible, and treating with phenothiazine to eliminate intestinal worms which add to the weakening effect of the husk worm. Sometimes injections into the windpipe assist.

Liver fluke or fascioliasis. A disease mainly of calves and yearlings, caused by a flat worm or fluke. It usually arises after grazing in autumn on wet pastures infected with a very small snail which harbours the worm during certain stages of its development. The first signs of the disease are a falling away in condition, usually during the winter, associated with signs of anaemia. Diagnosis is confirmed by making an egg count of the droppings, and in cases of death, by finding changes in the liver such as the thickening of the ducts (pipey liver) containing the flukes. Treatment is by the administration of carbon tetrachloride to young cattle on poorish pastures, by the use of Filix Mass in other cases. Treatment should be carried out again with care as untoward results may be obtained. Liver fluke is a common disease of sheep, and the presence of sheep may increase the danger to cattle on the pastures.

Metabolic Disorders of Cattle. There would appear to have been a great increase during recent years in the number of digestive disturbances affecting dairy cattle. A few years ago, the only ailments of this kind that were common were diagnosed as indigestion and tympany of the rumen. Nowadays, partly owing to the advance in scientific knowledge, and partly owing to increased productivity and greater use of ley farming, many metabolic disturbances of different types appear to be common. Some of these conditions are due to a diminished amount of some constituent, such as calcium, in the blood. For example, milk fever is generally accompanied by hypocalcaemia, and can be cured by the injection of a suitable form of calcium. Other conditions are also connected with calcium, magnesium and/or phosphorus. These conditions include pregnancy toxaemia, transit tetany, lactation tetany, post-parturient dyspepsia, and shivering tetany. The actual cause of the lowered quantity in the blood of one or more of these elements or of a change in the Ca: P ratio is not always known, although in many instances a special strain placed upon the animal seems to help the outset of clinical symptoms. Several other diseases are more particularly concerned, it would appear, with a general unbalance of the rations. Acetonaemia or ketosis is more particularly a trouble associated with heavy milk yielders immediately after calving, and is clearly connected with an upset in the carbohydrate metabolism.

An equally common ailment is described as " bloat " or " hoven ". This trouble is usually associated with tympanitis, or excessive gas production of the rumen. It may be relieved only by a surgical operation. This tympany, however, is merely a symptom of the trouble. It may arise in the simplest of cases from a blockage in the alimentary tract, but in recent years it has often followed the release of cattle to new grown leys or re-seeded pastures. Sometimes animals may be so badly affected with tympanitis that they die in a short time. The condition is thought to be associated with the richness of the pasture; it may be due to some particular constituent of clover or other vegetation. To some extent it can be controlled by careful management, but no one form of management would appear to give complete prevention from all forms of this trouble. This is a subject which needs much greater research ranging from an examination of the various plants which go to make up the best pasture for the grazing animal to the effects of various constituents of the diet upon the health of the animal. Whatever may prove to be the cause of these various diseases, it is clear that metabolic disorders are becoming increasingly important to the dairy farmer, as they may not only lead to a temporary drop in milk yield, but not infrequently cause the death of a high producing animal. *See* Diseases, human; Management of cattle; Mastitis; Tuberculosis.

Refs.: Francis, Gaiger and Davies; Miller; Rogers; Wilson; Wooldridge (1954), *Farm livestock in health and disease*, London; Jordan (1933), *JDR*, **5**, 160; Edwards (1936), *JDR*, **7**, 291; (1938), *JDR*, **9**, 356; Watts (1940), *JDR*, **11**, 316; (1944), **13**, 340; (1949), *JDR*, **16**, 242; Blackburn (1952), *JDR*, **19**, 356; Steele-Bodger (1949), *IDC*, **1**, 474 (young stock); Atkinson *et al.* (1942), *Special Report on Diseases of Cattle*, Washington ; Lovell and Hill (1940), *JDR*, **11**, 225 (mortality in calves) ; Econ. Advis. Counc. (1934), *Report of the Committee on Cattle Diseases*, H.M.S.O.

DISINFECTANTS AND DISINFECTION. A disinfectant may be defined as a chemical substance or substances which can kill bacteria in utensils, on floors, etc. (*in vitro*) under practical conditions without disadvantages to human beings. As milk is such a powerful absorbent of odours (*see* Flavours) it is obvious that any disinfectant such as carbolic acid and the chlorphenols which have marked odours are automatically ruled out. The safest and best to use are the hypochlorites (*see* Chlorine) and the quaternary ammonium compounds (p. 879), the former being excellent for utensils and plant which can be flushed out with sterile water (*i.e.* containing 10 p.p.m. chlorine) and the latter being not only non-toxic for animals but also tasteless and odourless in the concentrations used.

In addition to general suitability, the factors controlling the efficiency of a disinfectant are : (*a*) concentration ; (*b*) temperature ; (*c*) time of application ; (*d*) acidity or *p*H, and, of course, the absence of organic matter and the nature of the bacteria concerned. *See* Sterilisation.

Velocity of Reaction. Disinfection proceeds like a monomolecular action : Velocity = concentration × constant or $V = Ck$ or in other words, the rate of killing at any moment is proportional to the number of bacteria present.

The reaction velocity k is equal to $\frac{1}{t} \log \frac{B}{b}$ where t = time and B and b represent the initial and final numbers of bacteria.

Concentration. The effect of concentration of the disinfectant is given by the formula : $C^n t$ = constant or $n \log C + \log t$ = constant where C = concentration, t = time and n = constant for any one disinfectant.

Temperature. Killing increases geometrically with temperature, the formula being $\frac{k'}{k} = \theta^{(T'-T)}$ where k = velocity constant at temperature t, and k' at t' and θ = temperature coefficient.

Testing of Disinfectants. (i) The Rideal-Walker method compares a disinfectant in simple solution against phenol, the relative strength being described as a *phenol-coefficient*. (ii) The Chick-Martin test compares disinfectants in a 3 per cent. suspension of human faeces over a period of 30 min. (iii) The Phelps method is to determine the k, n, and θ values under defined conditions.

Refs.: McCulloch; Wilson and Miles; Richards and White (1949), *SAB*, No. 2, 61.

DISSOCIATION. All electrolytes, *i.e.* salts and other chemicals which conduct electricity in solution, split up into 2 or more charged radicles when dissolved in water. *See* Anions; Cations.

$$NaCl \rightarrow Na^+ + Cl^-$$
$$HCl \rightarrow H^+ + Cl^-$$
$$NaOH \rightarrow Na^+ + OH^-$$

As acidity is due to hydrogen ions (H^+) and alkalinity to hydroxyl ions (OH^-), it follows that the more H^+ produced from a given weight of acid in solution, the stronger will be the acid, *i.e.* the lower the *p*H. Similarly, the more OH^- produced by an alkali, the stronger the alkaline solution or the higher the *p*H. The degree of dissociation is thus a measure of the strength of the acid or alkali, a very strong acid like hydrochloric or a very strong alkali like caustic soda being practically completely dissociated in dilute solution. The degree of dissociation is expressed in terms of the *dissociation constant*.

DISSOCIATION CONSTANTS.

Acids	*Degree of ionisation (N solution at 18° C.)*	*Dissociation constants at 25° C.*
Nitric	0·82	
Hydrochloric	0·78	
Sulphuric	0·51	(2nd) 2×10^{-2} (18°)
Tartaric	0·08	$1{\cdot}1 \times 10^{-3}$; $6{\cdot}9 \times 10^{-5}$
Acetic	0·004	$1{\cdot}75 \times 10^{-5}$
Butyric		$1{\cdot}48 \times 10^{-5}$
Carbonic	0·0017	$3{\cdot}5 \times 10^{-7}$ (18°)
Citric		$8{\cdot}4 \times 10^{-4}$; $1{\cdot}8 \times 10^{-5}$; 4×10^{-6}
Lactic		$1{\cdot}38 \times 10^{-4}$
Phosphoric		$1{\cdot}1 \times 10^{-2}$; $7{\cdot}5 \times 10^{-8}$; $4{\cdot}8 \times 10^{-13}$ (18°)
Alkalis or bases		
Potassium hydroxide	0·77	
Sodium hydroxide	0·73	
Ammonium hydroxide	0·004	$1{\cdot}8 \times 10^{-5}$

DISTRIBUTION OF MILK. *See* Costings; Management of creameries, of pasteurising depots; Milk Marketing Board; Retail; Transport.

Refs.: Williams; Jones (1953), *JSDT*, **6**, 72; Bell, 78; Procter, 84; de Vries (1949), *IDC*, **4**, 262; Capstick, 272.

DOG MILK. *See* Mammals.

DOLPHIN FAT. This resembles butterfat chemically and is therefore more difficult to distinguish than most fats used for adulteration purposes.

Ref.: Williams, K. A.

DORNIC DEGREES. *See* Degrees.

DORSET BLUE. *See* Cheese, p. 190.

DOUBLE CREAM. A thick cream of high fat content, *e.g.* 48 per cent.

DOUBLE CREAM CHEESE. *See* Cheese, p. 190.

DOWN CALVING. Close to calving.

DRAINING OF CANS. *See* Effluents, p. 420.

DRENCH. A liquid medicine ; to give a liquid medicine to an animal.

DRESSING. *See* Cheese, p. 214.

DRIED GRASS. *See* Grass drying.

DRIED MILK. *See* Milk powder.

DROSOPHILA. *See* Insecticides.

DRUM DRYING. *See* Milk powder ; Campbell's process.

DRY ICE. Solid carbon dioxide.

DRYING OF MICRO-ORGANISMS. For the purposes of maintaining or sending cultures of micro-organisms, a modern method is to freeze-dry a culture in a suitable medium. Such dried preparations can be used after a long period and retain their original characteristics. Starter cultures are now preserved and dispatched in this condition. *See* Freeze-drying ; Starters.

DUCLAUX METHOD FOR ANALYSIS OF VOLATILE FATTY ACIDS. This method is based upon the fact that, on distillation of a mixture of fatty acids in water, they volatilise inversely according to their solubility, *i.e.* the least soluble distil first and the most soluble last.

The method is excellent for one or two acids, possible for three, but tedious and complicated for four or more acids. It was formerly frequently used for studying the breakdown of fat and lactose in the ripening of cheese, but has now been replaced by chromatography.

DUCTLESS GLANDS (OR ENDOCRINE GLANDS). Glands whose secretion passes into the blood stream instead of being conveyed through a duct. *See* Glands ; Hormones ; Milk secretion.

DUNG. *See* Faeces, bovine ; Dirt ; Routine tests.

DUNLOP. *See* Cheese, p. 191.

DUTCH CHEESE. *See* Cheese, Edam, p. 191 ; Gouda, p. 195.

DYES. Certain dyes, *e.g.* annatto, aniline yellow, etc., were formerly used for colouring milk, butter, and cream to increase the richness of their appearance especially in winter. Their use is now forbidden except for certain specified uses, *e.g.* annatto in cheese. Even this has been suspended since the war for purely economic reasons. *See* Annatto.

Ref.: Richmond.

E

EBERTHELLA. A genus of Gram-negative, motile, non-sporing rods, fermenting many carbohydrates to form acid without gas. The type species is *Eberthella typhosa*, the causative organisms of typhoid fever. In the 6th edition of Bergey this genus has been combined with the genus *Salmonella*. *See* Classification ; Diseases.

Refs. : Bergey ; Wilson and Miles.

EBULLITION. Boiling.

ECONOMIC NUTRITIONAL VALUES. *See* Table E 1.

ECONOMICS. *See* Costings ; Management of creameries, of pasteurising depots ; Milk marketing; Prices; Retail; Transport.

Refs. : Enock ; Williams ; Bartlett (1941), *The Price of Milk*, Danville, Ill. ; (1946) *The Milk Industry: A Comprehensive Survey of Production, Distribution, and Economic Importance*. New York ; Beecham (1943-45), *Milk Investigation Scheme*, Rep. Nos. 4-9, Oxford ; Bridges (1943), *Milk Production : A Study of Variations in Costs* 1934-39, Oxford ; Campbell (1940), *Farm Management*, London ; Cohen (1936), *The History of Milk Prices : An Analysis of the Factors Affecting the Prices of Milk and Milk Products*, Oxford ; Cripps (1938), *The Distribution of Milk ; A Study of Town Delivery Costs*, Oxford ; Forrester (1937), *The Fluid Milk Market in England and Wales*, H.M.S.O. ; Walworth ; Liversage (1926), *Economics of Production of Grade A (T.T.) Milk*, Oxford; Wyllie (1953), *Farm Management*, London.

ECZEMA. A peculiar form of this disease, known as *milker's eczema*, may affect those who regularly milk cows.

EDUCATION, DAIRY. *See* Agricultural colleges.

Refs. : Soc. Dairy Tech. (1945), *Report of the Education Committee*, London ; Min. Agric. (1945), *Agricultural Education in England and Wales*, H.M.S.O. Crossley, (1948), *JSDT*, **2**, 14.

EDAM. *See* Cheese, p. 191.

EFFICIENCY. In general terms, efficiency is measured by the ratio of useful or desired energy (or other quantity) to that applied or fed in.

EFFICIENCY IN DAIRIES. *See* Costings; Design of dairies; Management of dairies.

Refs. : Hilding (1949), *IDC*, **4**, 17 ; Green, 33.

EFFLORESCENCE. (i) Flowering. (ii) The evaporation of water from a crystalline water-containing substance to give a powdery material.

EFFLUENTS IN DAIRIES. A substantial problem arising in almost any industry is the disposal of the waste waters which are incidental to the various processes. These vary widely in volume and character according to the nature of the industry. Thus waste pickle liquors from metal industries consist largely of an acidic solution of metallic salts, waters from the washing of coal contain large quantities of suspended matter, and waste waters from the retting of flax contain a high proportion of organic matter in solution. Effluents from dairies and creameries, pasteurising depots, cheese factories, and factories manufacturing milk products, may contain appreciable quantities of milk constituents, including casein and other milk proteins, lactose, fat, and inorganic salts. In fresh milk these are present either in solution, in colloidal suspension, or as an emulsion, but in an effluent, the state in which they occur will depend on the treatment to which both the raw material and the effluent are subjected before the latter is discharged. Thus development of acidity or treatment with acid or rennet results in deposition of casein, and if a proportion of this is discharged, the effluent may contain an appreciable quantity of solids in suspension, as well as organic matter in solution.

TABLE E.1

DAIRY PRODUCTS AND OTHER FOODS

(Price to consumer in pence per unit of food constituent (1939))

	Average price per 100 g	Protein (100 g)	Fat (100 g)	Carbo-hydrate (100 g)	Calories (1000)	Calcium (1 g)	Phos-phorus (1 g)	Iron (10 mg)	Potas-sium (1 g)
Flour	0.44	4.1*	490	0.55*	1.25*	24	4.3*	4.8*	3.06*
Bread (white)	0.44	5.5*	—	0.75*	1.75*	19	6*	4.4*	3.8*
Potato	0.22	10.5	—	1*	2.5*	30	5.5*	3*	0.4*
Beef	2.43	11.4	7.6*	—	6.3	420	10.2	5.3*	8.4
Milk	0.6	18	16	12.5	9	5*	6.3*	75	4*
Cheese (Cheddar)	2.3	9.2*	7*	—	5.5	3*	4.2*	40	20
Cheese (cream)	10.6	214	12.3	—	9.8	360	240	760	226
Butter	3.5	875	4.1*	—	4.4	—	146	220	234
Bacon	3.3	26.5	6.8*	—	6.5	244	35	37	12.3
Herring raw	1.3	7.9*	7.3*	—	4.8	13.1	4.9*	9	4.2*
Egg	2.9	24.5	23.5	—	18	52	13.3	11	21
Sugar	0.66	—	—	0.66*	1.67*	—	—	—	—
Honey	4.0	995	—	5.2	13.8	750	234	102	78
Apple	1.32	660	—	14.2	36.7	472	197	58	13.9
Orange	1.32	220	—	20.6	49	42.6	74	53	8.9
Beer	0.88	293	—	27.5	16	80.8	41	176	15.7
Margarine	1.45	724	1.7*	—	1.8*	353	121	48	290
Calcium carbonate				—	—	0.03	—	—	—
Iron chloride ($FeCl_3$)		—	—	—	—	—	—	0.0005	—
Potassium phosphate (K_2HPO_4)	—	—	—	—	—	—	0.7	—	0.3

* — cheapest forms of various nutrients

Such effluents cannot be discharged to rivers or streams without causing pollution, with resulting detriment to the life of fish and other aquatic organisms and to the amenities of the district. Their discharge may also have an adverse effect on livestock using the water of the stream for drinking purposes and on the quality of any water supply which may be withdrawn for general purposes further downstream.

The effect of an effluent on fish may be due to direct poisoning, as is known to occur through the presence of heavy metals, such as copper or zinc, or of materials such as cyanide occurring in the effluents from coke ovens and from electroplating. Waste waters not containing any directly toxic material may, however, kill fish through depleting the stream into which they are discharged of dissolved oxygen. Organic matter in an effluent encourages the growth of bacteria in the stream. These organisms oxidise the organic matter and in the course of aerobic respiration utilise the oxygen dissolved in the water. Unless the stream is reoxygenated by aeration, the amount of dissolved oxygen falls so low that it may fail to support the life of fish.

Cattle may be affected by drinking water to which trade wastes containing toxic materials such as cyanides have been admitted and off-flavour in the milk due to cattle grazing along a stream to which certain wastes had been discharged has been reported. A water supply drawn from a polluted stream may be adversely affected in colour or turbidity or through the presence of dissolved impurities. It may also have a high bacterial count from discharge of an effluent carrying a heavy bacterial load. In rural districts where surface waters may be used in dairies for cooling or for washing bottles or churns, these considerations are important. The quality of the water used for these purposes should be above suspicion.

It is clear that disposal of effluents is important in dairying for two main reasons: those responsible for the management of a dairy or factory should know how discharge of waste waters from other manufacturing establishments may affect their own economy and, at the same time, they should appreciate the polluting effects of effluents from their own premises and be conversant with the main principles of their treatment and disposal. A comprehensive account of the methods by which various waste waters may be treated has been given by Southgate (*Treatment and Disposal of Industrial Waste Waters*, H.M.S.O., 1948), and the reader is referred to this work for a more detailed consideration of the subject.

If the situation of the factory and the character of the effluent are suitable, the most convenient method of disposal is by discharge to the local sewer, the effluent being treated in admixture with sewage at the sewage-disposal works. This, however, is not possible either if the polluting load carried by the effluent is so great that it is beyond the capacity of the works to deal with it or if the effluent contains substances which interfere with the processes of purification. In such cases preliminary treatment at the factory is necessary. Many effluents are amenable to treatment by biological methods similar to those in use at a sewage works. To assess the importance of the problem involved in disposing of effluents from dairy premises, it is therefore necessary first to understand what constitutes pollution, how polluting strength is measured, and how it may be reduced by suitable treatment.

What Constitutes Pollution and How it is Measured. Sufficient has been said to indicate the general nature of pollution. Most effluents, including those from dairy premises, owe their polluting properties to their content of organic matter.

Legal powers to prevent pollution of rivers, which are now vested in Local Sanitary Authorities, County Councils, or Rivers Boards, date from the Rivers Pollution Prevention Act, 1876, and the Local Government Act, 1888. The Royal Commission on Sewage Disposal published results of a comprehensive investigation of the subject, together with recommendations as to the standards which should be required in effluents discharged to rivers, in a series of Reports, 1898 to 1915. Further recommendations were made by the Joint Advisory Committee on River Pollution (1930). The Salmon and Freshwater Fisheries Act, 1923, stipulated that sewage was not to be discharged into waters containing fish to such an extent as to poison or injure the fish, spawning grounds, spawn, or food of fish. The Public Health (Drainage of Trade Premises) Act, 1937, of which an excellent account has been given by Garner (*J. and Proc. Inst. Sewage Purif.*, 1940, 47), provides that owners of trade premises shall be enabled to make agreements with the local authority to discharge their effluents into the local sewer, the local authority having the right to impose certain conditions. In the event of failure to agree the Minister of Health has the right to arbitrate in the dispute and to make suitable by-laws. Recently (1948), a Rivers Board Bill, based on the Report of the Central Advisory Water Committee (1943) has been passed by Parliament. This Act empowers the Minister of Health and the Minister of Agriculture to set up Rivers Boards which shall control the rivers of England and Wales in relation to pollution, land drainage, fisheries, and water supply.

The standard recommended by the Royal Commission for effluents discharged to non-tidal streams has been generally recognised as a fair criterion. It is based on the facts that the suspended matter discharged with an effluent may be responsible for silting up the bed of a stream and that the organic matter serves as food for and is oxidised by growth of bacteria, which in turn use up the oxygen dissolved in the water. The Commission recommended that, except in cases where the dilution is exceptionally high, an effluent should not contain more than 3 parts per 100,000 of suspended solids and should not absorb more than 2 parts per 100,000 of dissolved oxygen when incubated for 5 days at 18·3° C. The oxygen so absorbed is a measure of the amount of organic matter (and other oxidisable substrates) oxidised by bacterial respiration and is known as the *Biochemical Oxygen Demand* (B.O.D.).[1] This value is best determined [2] by estimating by the Rideal-Stewart modification of Winkler's method, both before and after incubation, the oxygen dissolved in a suitable dilution of the effluent contained in a completely filled and closed bottle. The principle of the test depends on formation of a precipitate of manganous hydroxide which rapidly absorbs the oxygen dissolved in the liquid with formation of higher oxides or hydroxides of manganese. Acidification in the presence of an iodide results in release of an amount of iodine chemically equivalent to the oxygen content of the sample. Interference due to nitrite (which commonly occurs in effluents) or to certain types of organic matter is avoided by preliminary treatment of the sample with permanganate.

Suspended solids are determined either by passing a measured volume of effluent through a Gooch crucible, packed with asbestos, and weighing the crucible and its contents in the dry condition before and after passage of the effluent, or by concentrating the suspended matter by centrifuging and then discarding the supernatant liquid ; the residue is washed with water and centrifuged again before being evaporated to dryness and weighed.

Another criterion of polluting strength frequently adopted is the *amount of oxygen absorbed by the effluent from acid permanganate in 4 hr.* (4 hr. O.A.).[3] In this test, a measured volume of the sample is mixed in a 4 oz. glass-stoppered bottle with a measured volume, constituting a large excess, of an N/80 solution of potassium permanganate in the presence of an amount of 25 per cent. sulphuric acid approximately equal to one-fifth of the volume of permanganate solution.

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[1] In this article, figures for B O.D. will refer to values as " parts per 100,000 ".

[2] For details of this and other tests the reader is referred to : (1) *Methods of Chemical Analysis as Applied to Sewage and Sewage Effluents* (1929), Ministry of Health, H.M.S.O., London ; (2) *Standard Methods for the Examination of Water and Sewage* (1946), American Public Health Association, 9th ed., New York.

[3] Figures given in this article refer to values as " parts per 100,000 ".

TABLE Ef 1

Analytical Data (average results over 11 year period) Illustrating Effect of Treatment of Sewage in Sedimentation Tanks followed by Activated Sludge Process

(After Townend and Lockett, from paper presented to Institute of Sewage Purification July, 1947)

Analytical results parts per 100 000	*Raw sewage*	*Settled sewage*	*Activated sludge effluent*	*Purification calculated on influent in each case, effected by*		
				Sedimentation tanks (*a*)	*Activated sludge process* (*b*)	*Combined processes* (*a* + *b*)
				%	%	%
Oxygen absorption from acid $KMnO_4$, 4 hr at 26.7°C	7.96	4.62	1.13	42	76	86
Ammoniacal nitrogen	3.77	3.92	1.62	—	—	—
Albuminoid nitrogen	0.80	0.46	0.085	43	82	89
Nitrous nitrogen	—	—	0.28	—	—	—
Nitric nitrogen	—	—	1.20	—	—	—
Chloride (as chlorine)	10.3	10.3	9.9	—	—	—
B.O.D., 5 days at 18.3°C	30.0	16.8	0.83	44	95	97
Suspended solids	23.5	6.9	0.7	71	90	97

The contents are shaken with a gentle rotary motion and the bottle is placed for 4 hr. in a water bath thermostatically controlled at 26·7° C. At the end of that period, the amount of oxygen absorbed from the permanganate by the sample is determined by titrating the excess of permanganate remaining against a standard solution of N/80 sodium thiosulphate. For strong sewages and trade wastes, N/8 solutions of permanganate and thiosulphate are used in place of N/80 solutions.

If more comprehensive information as to the condition of an effluent is required, determinations may be made of total solids, total nitrogen, free and saline ammonia, albuminoid ammonia, nitrite and nitrate, and chloride.

Representative values for these chemical characteristics are given in Table Ef I.

Nature of Sewage and Methods of Treatment. Sewage is the liquid resulting from the water carriage system of disposing of the waste products of a community. *Domestic sewage* consists of the wastes from toilets, baths, lavatories, and sinks in dwelling houses, institutions, and business premises. *Surface drainage* consists of the run off from streets, roofs, and similar surfaces. Waste liquids resulting from industrial processes are known as *trade wastes*. In the *combined system* of sewerage the same sewer carries all these waste waters together with ground water gaining entrance by infiltration. In the *separate system*, surface waters and domestic sewage are carried in separate sewers.

TABLE Ef II

VARIATIONS IN THE VOLUME AND COMPOSITION OF SEWAGE[1] ARRIVING AT A TREATMENT WORKS OVER A PERIOD OF 24 HR.

(*Results at one rural works obtained by Water Pollution Research Laboratory*)

Time	*Rate of flow of sewage (gal. per hr.)*	*B.O.D.*	*4 hr. O.A.*
10·00	8200	49·0	8·50
12·00	8600	50·6	10·55
14·00	8400	48·8	10·35
16·00	7600	45·6	9·35
18·00	7600	45·0	10·45
20·00	7100	37·8	8·90
22·00	6600	27·0	5·10
24·00	6300	19·3	4·27
2·00	5100	17·5	3·40
4·00	4600	10·3	2·70
6·00	4600	9·9	2·20
8·00	5800	14·2	2·73

[1] The samples were of crude sewage but were settled in the laboratory for 2 hr. before examination.

The volume and composition of sewage arriving at a treatment works vary considerably over the 24-hr. period (*see* Table Ef II) and are also much affected by the weather. In this country the average volume of sewage per day per head of the population served is between 35 and 50 gal. As a rough index of the strength, it may be taken that in dry weather the average B.O.D. of crude sewage is about 40 parts per 100,000 and the content of suspended solids about 20 parts per 100,000.

Sewage must receive adequate treatment before being discharged to inland waterways. One of the oldest methods used, which still survives in some localities, was by *disposal on land*, a method which formed the basis of the sewage farm.

Agricultural land is laid out in furrows about 3 ft. apart and sewage, from which preferably the settleable solids have been removed, is discharged into the furrows at such a rate that it is absorbed in about half an hour. The land is ploughed periodically to a depth of about 12 in. Disadvantages of the process are: (1) Considerable areas of land are required. (2) Many trade wastes inhibit the growth of crops. (3) It is undesirable to grow food crops on land which may contain appreciable numbers of human pathogens, and (4) under certain conditions, sewage applied in large quantities to land may gain entrance to underground or surface water supplies.

Modern methods of disposal are based on biological treatment.

General Plan of Sewage Works. Treatment at most English sewage works follows a standard pattern which is illustrated in Fig. Ef 1. Large pieces of solid material are usually removed by passing the sewage through *screens* which in smaller works consist of a grid of inclined steel bars; these solids are either disposed of separately or comminuted and returned to the incoming sewage. Grit is removed in *detritus tanks.* The main removal of sludge occurs in the *settling tanks,* which are usually rectangular in shape and with a capacity equivalent to 10 to 15 hr. dry weather flow (or even larger). The settled sewage is then subjected to treatment designed to reduce the polluting strength to the standard required for final discharge—usually either in *percolating filters* or in an *activated sludge unit.* The humus produced by the former and the excess activated sludge produced by the latter process are removed by settlement in *humus tanks* or *settling tanks* with a retention period of at least 4-hr. dry weather flow, and only the supernatant liquid is discharged to a river. Settled sludge both from the primary sedimentation tank and from the final settling tank is withdrawn periodically and the combined material is usually dried in sludge-drying beds. In larger works it is usually digested in specially constructed chambers where methane fermentation sets in and the organic matter is broken down; the digested sludge is then pumped to drying beds. The final products are generally used on agricultural land as manure.

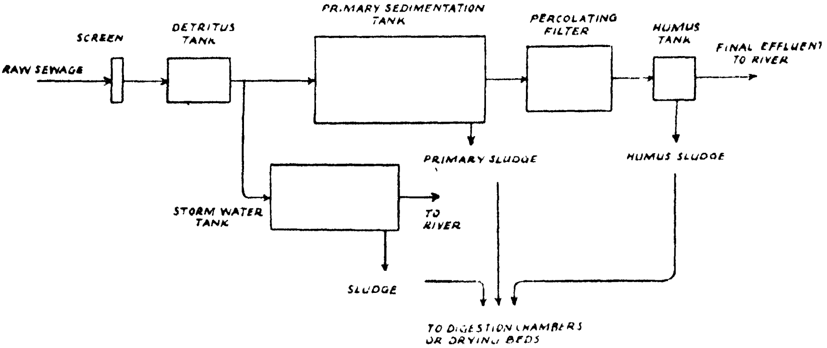

FIG. Ef 1.—*Diagram Illustrating Main Stages in Disposal of Sewage by Biological Treatment.*

Treatment in Percolating Filters. The percolating filter is the most popular form of biological treatment in this country, where many years of usage have proved its efficiency in treating sewage which varies widely in strength and in the proportion and kind of industrial waste it may contain. The filter—which is not a filter at all in the usually accepted sense of straining solid material out of a liquid—consists of a bed commonly about 6 ft., but sometimes as much as 12 ft., in depth and which is filled with graded " medium " which may range in size from ¾ in. to 3 in. in different filters. In some filters a layer of medium measuring 4 in. to 6 in. is placed at the bottom. This medium is usually coke, clinker, or gravel, but may be limestone, slag, coal, or hard sandstone. Adequate underdrainage of the filter is necessary, *e.g.* by a system of half tiles laid on a concrete floor. Filters may be either rectangular or circular, and the sewage is distributed evenly on to the surface of the filter either by fixed spray nozzles, by a rotating arm for the circular filter, or by a travelling distributor which carries a trough of sewage from end to end of a rectangular filter.

Continued percolation of sewage through a filter results in growth on the surface of the pieces of medium of *biological film.* Microscopic examination of stained preparations of this film show that it consists of a mass of bacteria and fungal hyphae embedded in mucoid material which also entrains a variety of protozoa. This film presents a very large surface of biologically active material, and the colloidal and dissolved substances in sewage are adsorbed by the film or diffuse into it and are rapidly acted upon by the extensive microbial population. The predominant flora of the biological film changes with increasing depth. In the upper layers it consists mainly of organisms which attack the organic matter, *e.g.* proteolytic bacteria which degrade proteins and amino acids to ammonia, and micro-organisms which ferment carbohydrates to acids or oxidise them to carbon dioxide. In the lower layers, where the film is dealing with sewage from which most of the organic matter has been removed, the main change taking place is oxidation of ammonia first to nitrite and then to nitrate. Application to a filter of sewage containing a particular type of constituent may result in development in the biological film of a flora adapted to attack that material. For example, filters treating sewage containing gas liquor acquire the property of oxidising thiocyanates and phenols, and a filter dosed with sewage to which lactose has been added builds up a bacterial flora which ferments lactose and then destroys the products of fermentation.

The increase in biological film occurring in this way is balanced by a process of sloughing which is greatly assisted by the activities of Oligochaete worms and the larvae of flies (particularly *Psychoda* species) which live embedded in the film. This process results in continual release of small pieces of the film which are washed from the filter by the percolating sewage and appear in the effluent as *humus.* Passage of the effluent through humus tanks allows this to be retained as a sediment so that the final effluent discharged to the river contains relatively small quantities of suspended matter.

The net result of treatment in a percolating filter which is working efficiently is thus to remove organic matter, oxidise ammonia, and so to yield an effluent which is relatively clear and contains an appreciable amount of nitrate.

For treatment in a percolating filter to be satisfactory, the B.O.D. of the liquid applied to the filter should not in general exceed about 25 to 40 parts per 100,000 and the rate of application should be reasonably steady and should be of the order of 50 to 100 gal. per cu. yd. of filtering medium per day. Continual overloading of a filter leads to excessive growth of film and of deposited solids, particularly in the upper layers of the filter, resulting in partial clogging. Liquid applied to the filter then finds difficulty in percolating through the medium and tends to remain on the surface—a condition known as *ponding.* The rate at which a filter can treat a given liquid may be much increased by adopting either filtration with recirculation of effluent or alternating double filtration, methods which are of particular interest in the treatment of waste waters from the dairying industry.

Filtration with Recirculation of Effluent. In this process a proportion of filter effluent (usually after settlement in a humus tank) is pumped back and mixed with the liquid being treated. The liquid applied to the filter, therefore, consists of sewage or of a mixture of sewage and trade waste diluted with its own effluent, the proportion depending on the rate of pumping. Results of several years' investigation of the process by the Water Pollution Research Laboratory have been given by Mills (*J. and Proc. Inst. Sewage Purif.*, 1945, II, 35) from whose paper the figures in Table Ef III have been taken. The method of operating this process is shown diagrammatically in Fig. Ef 2.

TABLE Ef III

FIGURES[1] ILLUSTRATING AVERAGE RESULTS OVER 3-MONTH PERIOD OF TREATMENT OF SEWAGE BY FILTRATION WITH RECIRCULATION OF PART OF THE EFFLUENT

Equal volumes of settled sewage and of settled filter effluent applied to filter. Settled sewage treated at rate of 245 gal. per day per cu. yd. of filtering medium.

	Results of analysis (parts per 100,000)			
	B.O.D.	*4 hr. O.A.*	*Ammonia (as N)*	*Nitrite + Nitrate (as N)*
Settled sewage	16.0	8.8	3.7	
Settled effluent	1.2	1.25	1.6	1.2

[1] Taken from data given by Mills (*loc. cit.*).

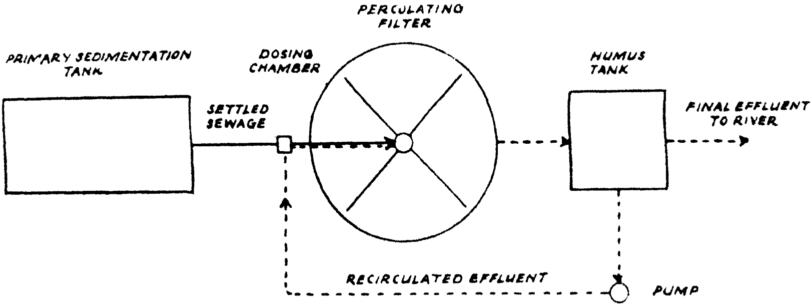

FIG. Ef 2.—*Diagram Illustrating Treatment of Sewage in a Percolating Filter with Recirculation of Effluent.*

Alternating Double Filtration. This process was developed by the Water Pollution Research Laboratory during an investigation of methods of disposing of waste waters from the dairy industry, which are particularly prone to cause blocking of filters. Results of this investigation and of later full-scale trials of the method applied to ordinary sewage containing trade wastes are given in three publications : (*a*) *Treatment and Disposal of Waste Waters from Dairies and Milk Products Factories*, W.P.R. Technical Paper No. 8, H.M.S.O., London, 1941. (*b*) Wishart, Wilkinson and Tomlinson, *J. and Proc. Inst. Sewage Purif.*, 1941, pp. 15 and 39. (*c*) Mills, *J. and Proc. Inst. Sewage Purif.*, 1945, II, 35.

It was found that the biological film causing blocking could be removed by applying to the filter the effluent from another filter. Investigations in the laboratory showed that the main constituent of such growth was a mat of fungal mycelium consisting mainly of species of *Sepedonium* and *Fusarium*. When either water or effluent was continuously applied, the character of this growth underwent a change. The compact mat of fungal mycelium developed large numbers of chlamydospores and the protoplasm became concentrated in these and in certain sections of the hyphae. The remaining sections appeared to be empty and to become the victims of bacterial attack, thus weakening the mechanical strength of the whole structure, which then broke up. In large-scale practice this period of starvation is ensured by employing two filters in series and periodically altering the order in which they receive the sewage. Thus, for a period (which may last for 1 to 7 days or sometimes longer) a filter receives settled sewage and then, for a similar period, receives the effluent from treatment of this sewage in the other filter. The process is illustrated diagrammatically in Fig. Ef 3 and representative results of operation of the process are given in Table Ef IV.

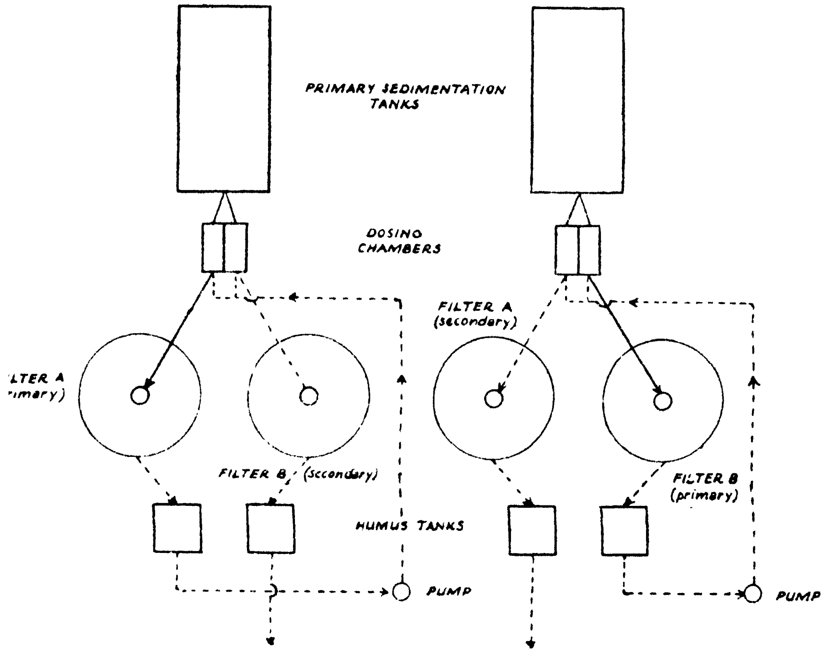

FIG. Ef 3.—*Diagram Illustrating Treatment of Sewage by Alternating Double Filtration.*

Enclosed Filters. The natural ventilation resulting from the system of underdrainage in ordinary percolating filters is usually considered sufficiently good for treatment of domestic sewage at ordinary rates. Efforts to improve the performance have, however, been made by enclosing the filter and supplying it with forced ventilation. A circular filter completely enclosed in a concrete case is supplied with air from a fan in the hooded roof, the air passing downwards through the filter and out by a vent at the bottom. It is claimed that with this filter, conservation of heat and improved aeration result in better effluents and higher rates of treatment than are common with the open filter. Experimental evidence for this view is, however, not yet extensive.

Activated Sludge Process. When a current of diffused air is passed for a long time through sewage, the organic matter is eventually flocculated and, if the current of air is then stopped, the flocs will settle to the bottom as a brown sediment leaving a comparatively clear supernatant liquor. If the latter is drawn off, a fresh batch of sewage added, and the process of prolonged aeration repeated, a further quantity of sludge flocs is obtained. It is found that when the quantity of sludge thus built up forms an appreciable proportion of the total liquid (say 10 to 20 per cent.) a degree of purification, which was originally attained only after aeration for many days, is now accomplished in a few hours. The sludge produced in this way, and possessing this property of rapidly purifying the waste water with which it is aerated, is known as *activated sludge*. Microscopic examination of a sludge floc shows that, somewhat like the biological film from a filter, it consists of a mass of bacterial and fungal hyphae in a gelatinous matrix. Numbers of protozoa are also evident.

When activated sludge is aerated in admixture with sewage the first reaction is one of adsorption, much of the colloidal and dissolved matter of the sewage being adsorbed to the surface of the activated sludge floc. During a subsequent period of prolonged aeration this amorphous material is used by the mass of micro-organisms as a source of food and, in the process, is converted partly to the substance of new cells and partly to products of fermentation and oxidation. If the aeration is sufficiently vigorous and prolonged, oxidation of the organic matter is followed by oxidation of the ammonia to nitrate. The protozoa appear to play an essential part in clumping the bacteria and thereby helping to yield a clarified effluent. Conditions in an activated sludge tank tend to encourage a uniform population of protozoa the character of which depends on factors such as strength and composition of sewage and degree of aeration. Thus ciliates predominate when the effluent is of good quality and flagellates only when it is poor.

TABLE Ef IV

FIGURES[1] ILLUSTRATING RESULTS OF TREATMENT OF SETTLED SEWAGE (*a*) BY SINGLE FILTRATION, AND (*b*) BY ALTERNATING DOUBLE FILTRATION

(*Average results for periods of about* 3 *months in each case*)

Rate of filtration (gal. per day per cu. yd.)		*Period of alternation*	*Sample analysed*	*Parts per* 100,000	
Single filter	*Double filter*			*B.O.D.*	4 *hr O.A.*
60	160	Weekly[2]	Settled sewage	14·5	9·0
			Effluent from		
			Single filter	1·10	1·40
			Primary filter	2·05	2·35
			Secondary filter	0·90	1·50
67	252	Daily[3]	Settled sewage	13·0	9·35
			Effluent from		
			Single filter	0·90	0·95
			Primary filter	1·65	1·40
			Secondary filter	0·95	0·95
65	244	Daily[4]	Settled sewage	15·0	10·2
			Effluent from		
			Single filter	0·70	1·10
			Primary filter	2·15	2·05
			Secondary filter	0·90	1·30

[1] Taken from data given by Mills (*loc. cit.*).

[2] Observations made in 1940-41; primary effluent settled before pumping.

[3] Observations made in 1942-43; primary effluent settled before pumping.

[4] Observations made in 1943-44; primary effluent not settled before pumping.

The commonest method employed for aeration in this country is by means of compressed air which is broken up into fine bubbles by means of diffusers.

Settled sewage flows into an aeration tank usually 10 ft. to 15 ft. deep and with a capacity equal to 8 to 24 hr. of dry weather flow. At the bottom of the tank are rows of porous plates set in iron boxes and arranged either longitudinally in furrows, so as to give uniform aeration throughout the whole of the liquid in the tank, or along one side of the tank, so as to impart a rotary motion to the liquid. Compressed air is supplied to the diffusers by a system of pipes. The effluent from the activated sludge tank is settled in an upward-flow sedimentation tank from which the settled sludge is continually removed to a distributing chamber. Part of the sludge is returned to the inlet of the aeration tank and the rest is removed for disposal.

Aeration may be provided by mechanical means instead of by diffused air. Thus, in the " Sheffield " process, aeration and agitation are ensured by a series of revolving paddles which force the liquid to travel along a system of channels in a shallow tank. In the Simplex system a vertical pipe, in the centre of a square tank with a hopper-shaped bottom, draws the liquid continuously from the bottom layers and sprays it over the surface by means of a revolving head, thus ensuring continuous aeration and mixing. The Kessener process involves continuous agitation of the surface of the liquid by means of revolving metal brushes.

The main parts of an activated sludge plant are illustrated by the simple diagram in Fig. Ef 4.

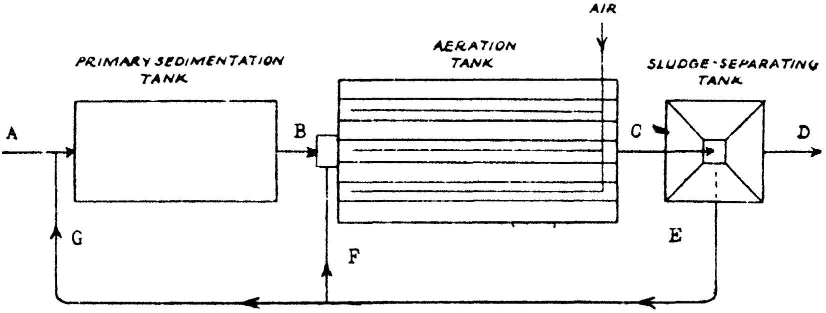

FIG. Ef 4.—*Diagram Illustrating Treatment of Sewage with Activated Sludge (adapted from diagram by Southgate, loc. cit.).* A. *Sewage from Detritus Tank.* B. *Settled Sewage.* C. *Mixture of Sewage Effluent and Activated Sludge.* D. *Final Effluent.* E. *Activated Sludge.* F. *Activated Sludge returned to Aeration Tank.* G. *Surplus Activated Sludge to Primary Sedimentation Tank.*

The activated sludge process is liable to be upset by fluctuations in the character of the sewage and by certain other factors. Thus " bulking " of the sludge, a condition which makes it difficult to separate the sludge from the liquid in the settling tanks, may be caused by insufficient aeration, by overloading the aeration tank, particularly with carbohydrates, or by returning to the tank sludge which is insufficiently active or stale.

In some sewage works, the sewage is given preliminary or partial treatment with activated sludge and the purification is completed by treating the effluent in percolating filters. This is known as the *bio-flocculation process.* By first removing in this way a proportion of colloidal matter, the sewage may be treated in percolating filters at a high rate.

Chlorination of Sewage and Sewage Effluents. Treatment of a sewage or of the purified effluent with chlorine may be recommended in certain circumstances to prevent septicity, to destroy pathogenic organisms, or to delay growth of micro-organisms so that the amenities of the district in the immediate neighbourhood of the outfall of a sewage works are protected from unsightly appearance and unpleasant odour. When chlorine is added to sewage or sewage effluent it reacts with organic matter and such inorganic materials as sulphide which may be present. The amount of chlorine, expressed as parts per million, required to satisfy this chemical affinity and to leave residual chlorine, detectable after a period of contact of 10 min. by a yellow colour on adding ortho-tolidine reagent, is known as the *chlorine demand.* When a dose of chlorine less than this amount is added to a liquid, the chlorine is partitioned between the chemical constituents with which it reacts on the one hand and the cells of micro-organisms on the other hand. Some bacterial destruction occurs under such conditions but efficient disinfection occurs only when doses of chlorine in excess of the demand are added. Data shown in Table Ef V illustrate the fact that not only is the percentage destruction of bacteria greater but the period of lag before aftergrowth occurs is longer with doses above the demand than with smaller doses.

TABLE Ef V

EFFECT ON BACTERIAL COUNTS OF TREATMENT OF SEWAGE WITH DIFFERENT DOSES OF CHLORINE

Chlorine demand of sewage (p.p.m.)	*Period of contact*	*Dose of chlorine added (p.p m.)*			
		1	2·5	5	10
		Plate counts (millions per ml)			
9-10	0 . .	8·7	8·7	8·7	8·7
	15 min . .	7·1	6·2	0·6	0·1
	2 days . .	10·0	14·0	17·2	0·2

TABLE Ef VI

EXAMPLES OF TOXICITY TO RAINBOW TROUT OF (*a*) EFFLUENT FROM DOMESTIC SEWAGE WHEN TREATED WITH A DOSE OF CHLORINE SLIGHTLY IN EXCESS OF THE DEMAND, AND (*b*) EFFLUENT FROM SEWAGE CONTAINING GAS LIQUOR WHEN TREATED WITH A DOSE OF CHLORINE GREATLY BELOW THE DEMAND

(*Effluent diluted with equal quantity of tap water before immersing fish*)

Type of sewage	*Chlorine demand of effluent (p.p.m.)*	*Amount of chlorine added (p.p.m.)*	*Residual chlorine (p.p.m.)*	*Average toxicity (T)*	*Mean period of survival of fish (100/T)*
Domestic	4-5	5	0·02	0·86	116 min.
		5 (destroyed by addition of thiosulphate)	nil.	<0·09	Non-toxic in 19 hr.
Containing gas liquor	11-12	0	nil.	<0·02	Non-toxic in 72 hr.
		5	nil.	5·1	20 min.

When sewage flows through sewers for long distances or at a low gradient before reaching the treatment works, growth of sulphate-reducing bacteria may result in the formation of appreciable quantities of hydrogen sulphide. In addition to causing nuisance at the works due to odour, this may lead to corrosion of the sewer through oxidation to sulphuric acid of the hydrogen sulphide escaping into the atmosphere in the sewer. Chlorine is sometimes added to sewage at a point some considerable distance before it reaches the works in order to prevent these troubles. It is usually found that doses of chlorine of the order of 25 to 50 per cent. of the chlorine demand are sufficient for this purpose.

Chlorination of sewage or sewage effluents should never be adopted in this country without careful consideration of possible consequences. Effluents are not infrequently discharged to comparatively small and sluggish streams so that the amount of dilution afforded is low. In such cases the chlorinated effluent may prove to be *highly toxic to fish.* This applies not only to effluents containing free chlorine, to which fish are well known to be extremely sensitive, but also to certain effluents to which comparatively small doses of chlorine are added and in which toxic chlorine compounds have been formed. Examples of the toxicity to rainbow trout of these two types of effluent are given in Table Ef VI, compiled from data obtained by the Water Pollution Research Laboratory.

Chemical Treatment. Sewage, particularly in industrial districts, and certain types of trade wastes, are sometimes treated with chemicals to remove suspended, colloidal, or dissolved organic matter. The chemicals most commonly used are alum, lime, copperas ($FeSO_4 . 7H_2O$), chlorinated copperas, alumino-ferric, and ferric salts. Alone or in certain combinations these substances form a precipitate which carries with it a proportion of the organic matter. The extent to which this occurs depends on the character of the waste liquor, the nature of the coagulant, and the *p*H value of the mixture. In large-scale practice, plants designed to operate intermittently, on the " fill-and-draw " principle, or continuously, may be used, depending on the character of the waste liquor (for further details and diagrams *see* Southgate (*loc. cit.*)). Preliminary tests in the laboratory should, however, always be made before designing such a plant.

Successful treatment may result in appreciable clarification and in reduction of the B.O.D. but the process does not usually yield an effluent of high quality and for this reason chemical treatment may have to be followed by some form of biological treatment. Treatment of milk washings with coagulants, for example, has been found to reduce the organic matter by some 30 to 70 per cent. A disadvantage of chemical treatment is that it leaves the problem of disposing of large volumes of sludge ; from some liquors this sludge is difficult to dry.

Microbiology of Sewage Purification.[1] The microbial flora of sewage is very varied and comprises the common organisms of the intestine, notably coliform bacteria, together with a heterogeneous collection of bacteria, fungi, and protozoa picked up from water and soil. Treatment at a sewage works results in a substantial reduction in total count, but the percentage decrease varies considerably and is higher in the warmer than in the colder months of the year. The counts commonly encountered in sewage and the order of reduction experienced in treatment in a single percolating filter, operated at a rate of 60 gal. per cu. yd. per day, are shown in Table Ef VII.

When biological film from a percolating filter or flocs of activated sludge are passed through an homogeniser the organisms embedded in the mucoid material are released and may be isolated by plating. The predominant organisms in activated sludge have been found in this way to be non-sporing rods (members of the genera *Achromobacterium*, *Chromobacterium*, and *Pseudomonas*), capable of bringing about comparatively little chemical change. The part played by these organisms in the treatment process has not been worked out, but American workers have isolated a floc-forming organism, *Zoogloea ramigera*, and claim that this is capable in pure culture of purifying sewage, either by the activated sludge process or by treatment in a percolating filter.

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[1] " The Biology of Sewage Purification ", Tomlinson (*J. & Proc. Inst. Sewage Purif.* (1939), Part 1, p. 225), gives a useful introduction to this subject.

Among the genera of fungi found in sewage treatment plants may be mentioned *Fusarium*, *Oospora*, and *Saprolegnia*, commonly isolated from the surface of filter beds, and *Sporotrichum*, frequently found in activated sludge. The so-called sewage fungus *Sphaerotilus* is a familiar object in stained preparations from sewage works. It may occur in unusual amounts in the condition known as " bulking " of activated sludge.

TABLE Ef VII

EFFECT ON BACTERIAL COUNTS OF TREATMENT OF SEWAGE IN A SINGLE PERCOLATING FILTER[1]

(*Plate counts on nutrient agar at 30° C. of samples taken at two different periods of the year*)

	Periods Aug. 4, 1943, to Nov. 19, 1943 and May 28, 1944, to July 11, 1944			*Period Dec. 3, 1943 to Mar. 21, 1944*		
	Temp. (°C.) (weekly average)	*Plate count of settled sewage (millions per ml.)*	*Reduction in count due to filtration (%)*	*Temp. (°C.) (weekly average)*	*Plate count (millions per ml.)*	*Reduction in count due to filtration (%)*
Maximum . .	20·0	12·9	99·4	13·0	8·3	94·0
Minimum . .	12·5	1·08	85·1	10·0	0·4	12·5
Average . .	16·3	6·7	93·9	11·5	1·72	72·4

[1] Data taken from *The Effect of Treatment in Percolating Filters on Bacterial Counts*, by Allen, Tomlinson and Norton. *J. and Proc. Inst. Sew. Purif.* **(1944)**, p. 115.

Many species of algae occur on the surface of filters where they are encouraged by the light. Members of the *Cyanophyceae* may sometimes produce large areas of dark-green growth on the surface, sufficient at times to interfere with passage of sewage through the filter.

That species of protozoa are an index of the correct working of the activated sludge process was proved by experiments on the treatment of milk effluents. When the sludge was in good condition and purification satisfactory, the protozoa present comprised the ciliates *Aspidisca costata* and *Euplotes charon*, two unnamed species of each of these two genera, and *Lionotus fasciola* ; the flagellates *Peranema* sp. and *Dinobryon* sp. ; the testaceous rhizopods *Arcella vulgaris*, *Trinema vulgare*, *Euglypha tuberculata*, and *Centropyxis aculeata*, with very few other flagellates.

Treatment of Dairy Effluents. Discharge to a stream of dairy wastes has been found (Pentelow, Butcher, and Grindley, " An Investigation of the Effects of Milk Wastes on the Bristol Avon ", *Ministry of Agriculture and Fisheries, Fisheries Investigation*, Series I, 4, No. 1 (1938), H.M.S.O., London), to result in a particularly rapid depletion of dissolved oxygen in the river water, in unsightly growth of sewage fungus, and in the deposition of black silt on the bed of the river.

The treatment and disposal of waste waters from dairies and milk products factories was the subject of an extensive investigation by the Water Pollution Research Laboratory (*W.P.R. Technical Paper*, No. 8 (1941), H.M.S.O., London). It was found that at milk pasteurising depots the volume of waste waters (comprising washings from floors, churns, coolers, pasteurising plants, tanks, etc.) was usually between 0·5 and 1·5 times the volume of milk handled. They commonly had a B.O.D. of 55 to 110 and they might carry away 0·5 to 1·0 per cent. of the total volume of milk. On an average, therefore, the wastes from a depot handling 10,000 gal. of milk a day would be equivalent in polluting strength to the untreated domestic sewage from a population of 1200 people. It was estimated that waste waters from a butter factory (washings from milk churns, butter churns, floors, etc.) would amount to between one and two times the volume of milk handled, and the average B.O.D. was between 150 and 300. Waste waters from cheese factories were similar in character and quantity. In the manufacture of condensed milk, evaporated whey, etc., waste waters may have a high B.O.D. derived from raw milk carried over during the condensing process. Thus the B.O.D. of the mixed condensates from a whey condenser was found to range from 125 to 520.

The findings resulting from the investigations of the Water Pollution Research Laboratory may be considered under the following headings.

Reduction in the Quantity of Milk Constituents Discharged to Waste. Both from the point of view of conserving nutrient material and of limiting the difficulty of disposing of waste, it is desirable that the quantity of milk or of milk products discharged should be reduced to a minimum. The nutritive value of whey and butter milk is high and there is a market for both products. On the other hand, their polluting strength is very great, whey, with a B.O.D. of 4,000, being 100 times as strong as crude domestic sewage. The practice of discharging these products to waste is therefore indefensible on either consideration. It was found that considerable reductions in the quantities of material discharged to waste could also be effected at most factories by simple modifications in factory operations.

TABLE Ef VIII

VOLUME OF MILK STILL RETAINED BY A 10-GAL. CHURN AFTER EMPTYING AND ALLOWING TO DRAIN FOR DIFFERENT PERIODS

Period of drainage (sec.)	3	10	20	30	60	90
Volume of milk still retained (ml.)	69	40	30	25	15	8

TABLE Ef IX

SAVING OF MILK EFFECTED AT A DISTRIBUTING DEPOT BY PROVISION OF DRAINAGE RACKS

Month	*Average volume of milk received daily during month (gal.)*	*Average biochemical oxygen demand of milk washings (parts per 100,000)*	*Estimated concentration of whole milk in effluent (%)*	*Estimated average daily loss of milk in washings (gal.)*	*Milk lost in washings as percentage of milk handled*
August 1935 .	20,000	91	0·8	180	0·9
February 1936 .	12,000	89	0·8	120	1·0
August 1936	24,000	62	0·6	80	0·3
February 1937 .	15,000	22	0·2	30	0·2

The time allowed for drainage of incoming churns, for example, was frequently insufficient and considerable economies were effected by providing drainage racks on which the churns remained inverted for 1 to 2 min. Results of experiments showing the volume of milk still retained after various periods of drainage, when a churn full of milk is emptied, are given in Table Ef VIII and the savings of milk effected in large scale practice by provision of additional drainage space at a distributing depot are indicated in Table Ef IX. Uniformity in the time allowed for drainage should be ensured so far as possible by arranging that churns are removed from the rack in the same order as that in which they are placed on it.

TABLE Ef X

TREATMENT OF MIXTURES CONTAINING EQUAL VOLUMES OF WHEY WASHINGS AND MILK WASHINGS BY THE ACTIVATED SLUDGE PROCESS

(*Average results* 26 *July to* 20 *September*, 1937)

Volume of diluted crude liquid treated : 9270 gal. per day.
Volume of sludge returned to aeration tanks : 2400 gal. per day.
Average period of aeration : 18 hr.

	Crude liquid	*Crude liquid after sedimentation*	*Settled and diluted crude liquid supplied to aeration tanks*	*Settled final effluent*
Temperature (°C.)	45·0	30·0	28·0	23·5
*p*H value	5·4	5·4	5·9	7·3
Parts per 100,000				
Biochemical oxygen demand	72·0	57·0	52·0	0·6
Oxygen absorbed from acid permanganate in 4 hr.	14·8	9·3	5·4	1·0
Dissolved oxygen	—	—	—	0·61
Total nitrogen (as N)	1·77	1·83	1·29	0·24
Ammonia (as N)	0·44	0·63	0·52	0·02
Nitrite (as N)	—	—	—	0
Nitrate (as N)	—	—	—	0
Soluble solids	38·0	42·8	56·1	29·8
Suspended solids	18·1	13·7	11·4	2·4

It was concluded that if losses from splashing and from drainage of churns were reduced to a minimum, there would still be an unavoidable loss amounting to about 0·1 per cent. of the milk handled.

In cheese factories the quantity of whey discharged to waste may be substantially reduced by not filling the vats so full nor stirring so vigorously that liquid is splashed on to the floor, and by rinsing the emptied vats with small quantities of water and adding the rinsings to the whey ; subsequent washing with larger volumes of water then results in less whey being discharged to waste. Similar considerations apply to butter churns. Drainage cocks on vats should either be of the non-splashing type or should be protected with a splash guard.

Treatment of Waste Waters by Anaerobic Fermentation. Though an appreciable reduction in the B.O.D. occurred on allowing diluted milk to ferment in open tanks for periods up to 40 days, the process was slow and was accompanied by an unpleasant smell. Whey washings showed little change during a period of fermentation of 48 hr.

Chemical Treatment. Addition of lime alone or of alumino-ferric in a concentration of 10 parts per 100,000 effected little change in the B.O.D. of milk washings. With milk washings containing 0·25 per cent. milk addition of alumino-ferric in concentrations of 50 to 200 parts per 100,000 reduced the B.O.D. by about 85 per cent.

Treatment with Activated Sludge. Preliminary small scale experiments showed that milk wastes could be successfully treated by the activated sludge process. Experiments were therefore carried out on a large scale in a plant comprising a primary sedimentation tank, a mixing tank for diluting with water or treated effluent, two rectangular aeration tanks operated in parallel and each measuring 16 ft. × 8 ft. × 6 ft. deep, and a final sedimentation tank. Compressed air was supplied to a series of porous plates set in the base of the tank along the longer sides. Activated sludge was built up by aeration of settled milk washings diluted with 6 volumes of water. Later, treated effluent was used in place of water and the proportion of diluent was reduced.

In general, it was found that treatment of dairy wastes by the activated sludge process was considerably affected by temperature. Thus in warm weather aeration for a period of 24 hr. reduced the B.O.D. of diluted waste waters from an initial value of 35 to 50 to a value of less than 1 in the final effluent, which was of excellent quality. Table Ef X illustrates the results obtained. In cold weather, satisfactory operation is only possible if the strength of the liquid treated is reduced or if the period of aeration is prolonged.

Difficulties encountered during operation of the process included " rising " of sludge, caused by the action of denitrifying bacteria in a well nitrified effluent, which released bubbles of nitrogen and tended to buoy up particles of sludge, and " bulking " of sludge. " Rising " could be cured by increasing the strength of liquid supplied to the aeration tanks or decreasing the period of aeration but these remedies had to be applied with caution as they tended to encourage " bulking ".

Treatment in Percolating Filters. Small-scale experiments showed that good results were at first obtained by treatment of milk washings in a single percolating filter, the B.O.D. being reduced by as much as 98 per cent. After a time, however, an excessive growth of film, in which solid nutrients, including globules of fat, were embedded, appeared on the surface, ponding took place and filtration was impeded. Further trials showed that this condition was avoided if the waste waters were treated by the process of alternating double filtration and a large-scale plant was installed at a factory.

The rate of flow and the composition of the liquid reaching the treatment plant were kept reasonably uniform by discharging the waste waters from the factory into rectangular balancing tanks. The crude liquid from these tanks then passed through a primary sedimentation tank of the Dortmund pattern, with a capacity of 1600 gal., and the settled liquid from this tank flowed by gravity to a small steel tank, provided with two V-notch flow gauges, in which it could be mixed with measured volumes of either river water or of final effluent from the plant. The diluted liquid was treated in two percolating filters, each measuring 25 ft. in diameter and about 4 ft. 6 in. in depth and packed with metallurgical coke, graded ¾ in. to 1½ in.[1] Effluent from the primary filter flowed through a humus tank and the settled effluent from this was treated in the secondary filter. Effluent from the secondary filter flowed through a similar humus tank, part of the settled effluent from which was returned to be used as diluent for the settled crude liquor, and the remainder was discharged to a river. All surplus sludge from the treatment plant, including material from the balancing, storage, and primary sedimentation tanks, and from both humus tanks, was discharged to two sludge-drying beds, which also received material from the activated sludge plant.

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[1] Larger filtering medium (*e.g.* 1½ in. to 2½ in.) has proved satisfactory in operation and may be advantageous in treating waste waters, such as those from butter factories, which contain a high proportion of fat.

The plant was operated by diluting the settled dairy wastes (milk washings, whey washings, or a mixture of these liquids) with final effluent to give a liquid with a B.O.D. of 20 to 30, by treating this at a rate of 160 gal. per day per cu. yd. of medium in the two filters together, and by changing the order of the filters about once a fortnight. Under these conditions a very satisfactory effluent was obtained with a B.O.D. of less than 1, suitable for discharge to a stream, and non-toxic to trout even when undiluted. Figures illustrating the results of operation are given in Table Ef XI.

TABLE Ef XI

TREATMENT OF MIXTURES CONTAINING EQUAL VOLUMES OF MILK WASHINGS AND WHEY WASHINGS IN TWO PERCOLATING FILTERS IN SERIES WITH PERIODIC CHANGE IN THE ORDER OF THE FILTERS

(*Average results, 3 July to 30 July 1937*)

Rate of treatment of diluted washings 160 gal. per day per cu. yd. of medium in the two filters together

	Crude liquid	*Crude liquid after sedimentation*	*Settled and diluted crude liquid supplied to primary filter*	*Settled effluent from primary filter*	*Settled effluent from secondary filter*
Temperature (°C.)	31.0	29.0	22.0	20.0	19.0
pH value	5.2	5.5	6.4	7.7	7.8
Parts per 100,000					
Biochemical oxygen demand	101.0	74.0	26.0	0.9	0.3
Oxygen absorbed from acid permanganate in 4 hr.	17.8	8.7	4.2	1.20	0.91
Dissolved oxygen				0.53	0.79
Total nitrogen (as N)	2.75	2.44	1.11	0.59	0.63
Ammonia (as N)	0.78	1.22	0.36	0.18	0.03
Nitrite (as N)	—			0	0
Nitrate (as N)	—	—	0.06	0.20	0.40
Soluble solids	54.0	51.0	38.9	29.1	33.6
Suspended solids	19.8	16.4	13.1	1.6	1.3

It was found that whey washings were less easily treated than milk washings, since they encouraged the growth of a tough fungal mat which was less easily dispersed by treatment with effluent when the order of the filters was reversed. Since purification of both these wastes is easier at temperatures of 20° to 30° C. than at lower temperatures it is advisable, when considering a treatment plant, to see that the waste liquors are cooled as little as possible between the factory and the filters. Where possible, the temperature of the liquid should be maintained by utilising any waste heat which may be available.

There were two main reasons why the treatment of dairy wastes by this method was considered to be superior to treatment by the activated sludge process:

(1) Discharge to the treatment plant for a short period of abnormally strong liquor results in only a temporary loss in efficiency. Under similar conditions the efficiency of an activated sludge plant may be seriously impaired for a long time. (2) The rate at which dairy wastes may be treated by the activated sludge process is rather lower than that which is usual for domestic sewage. In an alternating double filtration plant the rate of treatment may be considerably higher.

These difficulties in treating dairy waste waters are in general borne out by the results of experiments made by workers in America and on the Continent. Although Kessener and Rudolfs (*Sewage Wks. J.* (1934), **6**, 318) claim to have obtained very good results by the activated sludge process in two plants on the Continent, the period of aeration required—an average of about 3 days even in the summer months—appears to have been abnormally long.

An interesting account is given (Southgate, " Treatment of Milk Washings by Addition of Coagulants, Sedimentation, and Biological Filtration ", (1948), *DI*, **13**, 235) of the operation of plants at two factories in which partial treatment of milk wastes with chemical coagulants is followed by treatment of the effluents in percolating filters. In one plant the waste liquors are treated with a hot solution of alumino-ferric sufficient to provide a total concentration of 30 parts per 100,000, together with a hot solution of soda ash sufficient to raise the *p*H value of the mixture to 7·0. After settlement overnight, the supernatant liquor is treated on a percolating filter at a rate of about 340 gal. per cu. yd. of filter medium per day. The polluting strength of the crude waste waters, which are comparatively weak (*e.g.* in a composite sample the B.O.D. was 28·6, the O.A. 7·2) was reduced by about 75 per cent. by the chemical treatment and by about 95 per cent. by the combined treatment.

In the other plant, alumino-ferric only is added by immersing a block of the substance in the channel conveying the liquor to the sedimentation tanks (the concentration in the sample tested was 17 parts per 100,000). Settlement overnight is followed by treatment of the supernatant liquor on a percolating filter at a rate of about 60 gal. per cu. yd. of filter medium per day. The crude waste liquor is comparatively strong (B.O.D. 69, O.A. 15·2). Chemical treatment reduced its polluting strength by about 50 per cent. and the complete treatment by about 93 to 99 per cent.

No difficulty from ponding or blocking of the filter has been experienced at either factory, chemical treatment having apparently removed the substances most likely to cause these troubles.

Eh. *See* Oxidation-reduction potential.

EIRE.

Refs.: Dept. Agric. (1949), *IDC*, **4**, 620; Lyons (1941), *Dairy Legislation in Eire* Dublin.

EIJKMANN'S TEST. A test for the true faecal coli based upon ability to grow at 44° C. *See* Coliform organisms.

ELASTICITY. *See* Rheology.

ELECTRICAL CHARGES. *See* Anions; Cataphoresis; Cations; Dissociation.

ELECTRICAL CONDUCTIVITY. The conductivity of any material is the inverse of the resistance, which is measured by the amount of current passed when a known electromotive force is applied under standard conditions.

$$\frac{\text{E (volts)}}{\text{R (ohms)}} = \text{C (ampères) and } \frac{1}{\text{R}} = \text{conductivity (mhos).}$$

See Abnormal milk; Conductivity of milk; Detergent strength; Rapid abnormality indicator.

ELECTRICAL EQUIPMENT IN THE DAIRY. Conditions in the dairy are such that considerable care must be exercised in selecting electrical equipment for the various duties. Neglect in this respect may produce serious consequences, both in regard to danger to human life and plant breakdown. As a perishable product is being handled every day and duplication of machinery is not always practical, the importance of choice of the correct equipment and its proper installation and maintenance will be readily appreciated.

Electric motors and starters are required for reciprocating compressors, milk pumps, bottle washers, bottle fillers, conveyors, can washers and several other smaller, but essential activities. The types of equipment required for these duties depend on a number of factors such as local authority regulations and torque demands of the driven machines, degree of unloading during starting, surrounding conditions and power supply available. Consideration must also be given to the most suitable form of enclosure for the particular job.

Generally speaking there is little special electrical gear used in the dairy. This is a good feature, as it minimises capital expenditure and cost of replacement parts. Standard motors and starters should be employed throughout the dairy whenever possible and, provided the equipment gives reasonable performance and reliability, one make of motor and starter should be standardised throughout the dairy. This tends to reduce the spares carried in stock, as several motors are almost bound to be of identical type and output.

Electrical Terms. Several terms are frequently met with in practice and a few of these may be expressed in simple language;

Volt. Unit of electrical pressure or force required to overcome the resistance of a conductor to the flow of current.

Ohm. Unit of resistance.

Ampere. Unit of electrical current or flow.

Watt. Unit of measure of electrical power or work done.

Kilowatt. 1000 watts (approximately 1⅓ h.p.).

Horsepower. 746 watts.

kVA. This always arises in connection with A.C. motors. kVA in full is kilo-volt-ampere, and is employed as a measure of output of alternating current generators and also the input of supply to the main switchboard.

Alternating Current (A.C.) supply only will be considered when discussing this subject of electrical gear in the dairy. With the rapid development of the national grid system for power distribution the incidence of direct current in milk plants is comparatively rare.

By far the largest consumer of current in the dairy is the refrigerating plant. In many instances the compressor is the only unit in the dairy fitted with a slip ring machine. Where the larger capacity homogenisers are installed, this type of motor is also used. If the refrigerating plant is erected in a separate engine room, isolated from the steam and water atmosphere, standard protected enclosures are satisfactory for motors and starters.

The weatherproof squirrel cage motor is suitable for the various duties associated with the bottle washer and filler and the can washer. This also applies to milk pumps, although with these, suppliers usually arrange with the motor manufacturers to furnish stainless steel spindles on which the pump impellor is fitted.

The totally enclosed motor is not recommended for wet locations because of the danger that a certain amount of moisture will penetrate to the interior and condense when the motor cools down. For really wet situations a weatherproof machine is far more satisfactory, although sometimes this may be the totally enclosed motor with special gaskets. There is sometimes confusion of understanding with these various enclosures for electric motors, but in B.S. 205 "Glossary of terms in Electrical Engineering" there are precise definitions.

Although capital outlay will be increased, much can be said in favour of arranging all the starting equipment in a separate switch room with relays at the various operating points. This permits standard enclosures and the need for hoseproof and damp protecting starter casings is eliminated and in some measure the additional costs involved are offset. If operation is to be continuous, then the hoseproof enclosure must be used wherever steam and water are present. The wiring on the walls must be installed with great care, and all conduit points should be made air tight to avoid condensation inside the tube. If this is not possible, then provision for sloping the conduit to a common drain point should be made. The electrical connections at the motors and starters must also be made carefully in screwed conduit, and plastic bitumen for water sealing can be used to great advantage.

It is essential that the correct motor enclosure should be chosen for each application. Although infrequent, the practice of boxing a screen-protected motor against unfavourable conditions should be discontinued, as the ventilation of the machine will be restricted to such a point that serious overheating and eventual burn-out may be experienced.

Motors. Fractional horsepower motors are usually wound for single phase supply. Three-phase is used for machines of larger output. The three-phase induction motor is most commonly used, there being three main types: (i) squirrel cage motors ; (ii) slip-ring motors; (iii) auto-synchronous and synchronous induction. The first is employed on such duties as milk pumps, detergent pumps, bottle fillers, bottle washers, can washers, brine and chilled water pumps. The latter two are usually confined to the compressor of the refrigerating plant, although some deep well pumps are equipped with a slip-ring machine.

The squirrel cage motor has two essential components: (i) the stator, which is a hollow slotted core ; in the interior face of which is a three-phase winding and (ii) the rotor, which is also a cylindrical core, but with copper bars mounted parallel to one another and joined at the ends to two heavy rings. The rotor rotates and gives its motion to the driven unit to which the shaft, integral with the rotor core, is connected.

The slip-ring machine is similar to the squirrel cage unit except that the rotor is equipped with a set of three-phase windings wound in slots and with the leads connected to three bronze rings mounted on the shaft.

With 50 cycles per sec. current frequency the synchronous or stator field speed is a function of the number of pole pairs on the motor. For example, a 4-pole or 2-pole pair machine has a synchronous speed of 1500 r.p.m. The rotor speed can never attain the stator field speed because of friction and windage and the difference is termed the " slip ". The full load slip will vary according to design and make of motor, but will be around 3 or 4 per cent. If the slip is 4 per cent. on a 1500 r.p.m. synchronous speed motor, the full load or effective motor speed will be 1440 r.p.m.

It might be desirable to point out at this stage why squirrel cage motors with their higher efficiency and lower maintenance costs are not more generally applied and the reason that slip-ring machines replace them on the heavier duties.

When a squirrel cage motor is switched direct across the line on three phase current it will have a starting current of 5 or 6 times the running current. This creates a temporary voltage drop, and hence some limitation to direct switching of squirrel cage motors is imposed by supply authorities.

Whilst star-delta or other means of starting might be employed, there is a limit beyond which it is easier to install slip-ring motors with their integral facilities for easier starting whilst using current only slightly in excess of normal running current.

Reliability in electric motors must be maintained, and this demands the application of proper cooling effect to avoid excessive temperature rise. In dairy practice, three phase induction motors are generally fan cooled by the provision of fans mounted at one or both ends of the rotor shaft. The object is to ensure a constant stream of cool air over and through the motor casing.

In view of the varying conditions throughout the dairy, four main classes of enclosure may be installed: (i) screen protected; (ii) drip proof; (iii) totally enclosed ; (iv) weatherproof.

Apart from the compressor on the refrigerating plant, it is seldom that any special starting torque requirements arise in the dairy. The exacting demands of this unit determine the starter design.

Starters. Three types are in general use with squirrel cage motors: (i) direct on; (ii) star delta; (iii) auto transformer.

As implied (i) connects the three-phase supply directly to the stator windings, and is generally applied to small motors, and may be on push button or automatic control. Star delta (ii) or reduced voltage starting overcomes the high initial current difficulty by first connecting the motor in such a way that the voltage applied to each winding phase is one-third voltage value of direct-on starting and then switching over to three-phase for normal running. Auto-transformer (iii) starting results in a reduced three-phase voltage being supplied to the motor and as it runs up to speed the starter is advanced across the transformer tappings until full voltage is delivered and full speed attained.

In the starting of a slip-ring motor a resistance is applied across the slip rings of the motor. This resistance is gradually reduced as the motor runs up to speed. The rotor also reaches speed gradually being assisted to initiate its own resistive rotation without the high initial current surge. In practice this is achieved by a special type of resistance across the slip rings, and when the motor attains full speed these rings are short circuited, the brushes lifted from the commutator to reduce wear and from that moment the machine will operate as a standard squirrel cage type. This is the type of starting employed for the compressor drive on the refrigerating plant.

These various starters are fitted with protective devices, including overload coils for each phase and no-volt release coil which will operate in the event of a power failure. If the motor is overloaded then protection is afforded by the coils, and it is important that the cause of this offence is ascertained prior to resetting the overloads and restarting the motor.

Further protection is provided in the main safety device, namely, the fuse, which should be inserted in every motor circuit. The function of the fuse is to disconnect the motor from the main supply in the case of excessive current, due to overloading or to failure in insulation of the conductors. The supply company installs a further overall protection feature in the form of a circuit breaker which provides for excessive current surges.

Installation. Motors when awaiting installation should be stored in a clean, dry place, preferably with heating, to avoid condensation of moisture. If the storage time is long, then some motor enclosures will require careful examination before being placed in commission.

Before putting into use a motor that has been stored, it should be examined for any foreign matter that may have become lodged in it, and the insulation resistance tested. If this is less than one megohm, both between phases and to earth, the motors should be placed in a warm, dry place until this reading is obtained.

A motor having a low insulation resistance should not be run unless absolutely unavoidable, otherwise a breakdown may occur before the windings dry out.

The atmospheric and other conditions surrounding a motor have a big effect on the service given by the motor, but provided that the correct enclosure has been chosen in the first place, operation of the motor should be trouble free.

In spite of the sturdy and rugged construction of the modern induction motor, which will often operate successfully under appalling conditions, avoidance of conditions which have a deleterious effect is essential, if long, trouble-free service is to be obtained. A list of things to avoid, in both installing and running a motor, is given, as follows:

(*a*) *Vibration.* Whether caused by the driven machine, or transmitted from adjacent machinery, vibration will in time result in motor failure. Fatigue of the metal occurs and bearings wear quickly.

(*b*) *Dust and dirt.* The amount of cooling air passed through a ventilated motor is considerable, and dust and dirt present in the surrounding atmosphere is deposited on the motor windings and in ventilation ducts. In addition to causing overheating by preventing dissipation of heat, dust and dirt absorb any moisture, acids and stray oil that may be present in the surrounding atmosphere. This results in speedy deterioration of the motor windings and, sooner or later, a breakdown.

(*c*) *Moisture.* All motor windings are impregnated to give maximum resistance to the effects of moisture, but continued exposure to moist or wet conditions will reduce the insulation resistance. In addition, windings that have become moist will collect a deposit of dust from the cooling air. Even totally enclosed motors breathe and in time will absorb a certain amount of moisture, so that it is essential that motors are installed in as dry conditions as possible.

(*d*) *Overload.* All two- and three-phase motors are capable of sustaining the overloads specified in B.S. 168, but should continuous overload be imposed, the temperature rise will be excessive. Continued operation at high temperatures produces deterioration of the insulation, and the temperature should not be allowed to exceed 90° C. In this connection it should be noted that the feel of the outside of the motor to the hand is a very unreliable method of assessing temperature, and where a high temperature rise is suspected, a thermometer should be used, with the bulb placed in contact with the windings or cores.

(*e*) *Underload.* While underloading has no ill effect as far as the motor is concerned, it may have an effect on the cost of energy, depending on the tariff used by the supply authority. Where the charge is based on maximum kVA demand, the lower power-factor of the under-loaded motor will give a higher kVA maximum demand than would a motor of the correct output. When the energy charge is based on installed kW, the effect on cost due to over-motoring is immediately apparent.

(*f*) *Stray oil or grease.* Oil or grease should not be allowed to come into contact with motor windings, as deterioration of the insulation will occur.

(*g*) *Slide rails.* Slide rails should be firmly bolted to a concrete or other suitable foundation, with the surfaces of the rails parallel.

(*h*) *Connections.* The external leads to the motor should be of sufficient cross-sectional area to carry the full load current of the motor without undue heating or voltage drop.

Except in the smallest motors, which have straight through connections, cables should be soldered into the cable lugs provided in the motor terminal box. Bare cable ends should not be twisted under the cable lugs, as they may spring loose and cause short-circuits.

(*j*) *Starting.* Before starting up for the first time, check that all external connections are correct and all terminal nuts tight. The rotor should revolve freely. Check that the starter, if of the oil immersed type, is filled with oil to the correct level. The lags, if of the oil dashpot type, should be filled with oil. Mount all starters firmly and vertically, ensure that wiring is strictly in accordance with the diagram and that all connections are securely made. Care must be exercised so that clamps with terminal markings are not interchanged during the connecting up process. Clean dashpots and fill to the required level with the special oil provided and set these in line with the makers instructions.

Maintenance. Although the modern induction motor is simple, reliable and efficient, a certain amount of attention is desirable from time to time. No mechanical equipment will operate without some maintenance, and a few of the essential points are recorded below.

(*a*) *Inspection.* It is recommended that all motors are inspected at regular intervals, say once a month, unless conditions are very severe, when more frequent inspection should be carried out.

Some form of recording system will be found to be an advantage where a number of motors are in use, with log cards for each motor, on which are recorded all details of inspections carried out, maintenance required, and general conditions of operation. This will enable the position to be assessed at a glance and any modification desirable will be immediately apparent.

(*b*) *Routine cleaning.* Provided that the correct motor enclosure has been chosen to suit the conditions under which the motor works, cleaning should only be necessary at infrequent intervals.

Dust, dirt, oil, grease, etc., in the motor will result in choking of ventilation ducts and deterioration of insulation, and should not be allowed to accumulate.

Ventilated motors, even if installed under good conditions, tend to collect a certain amount of dust, due to the large volume of cooling air passing through the motor. The windings should be exposed by removing the endshields and the rotor and the dust removed by means of a vacuum cleaner. If this is not available, a jet of compressed air, under comparatively low pressure, should be used. The use of a fierce jet of compressed air results in the dust being blown farther into the ventilating ducts and interstices in the winding, where it packs tight and cannot be removed. Care should be taken to avoid damaging the insulation. Slip-ring motors have ventilated slip-ring covers, and these should be examined periodically. Any dust that has collected on the insulation of the slip-rings and brushgear should be removed, as this may cause trouble due to flashing over during starting. Petrol, trichlorethylene or carbon tetrachloride may be used for the removal of oil or grease. These solvents must, however, be used very sparingly, as, particularly with the older type of motor, an excess of solvent may loosen the insulating varnish. The effect on rubber cables makes it imperative that no solvent be allowed to come into contact with the leads between the winding and the terminal block.

When the oil or grease has been removed, the motor must be thoroughly dried out, preferably in the open air. Due precautions must, of course, be taken on account of the inflammable or objectionable nature of the fumes from the solvents.

(*c*) *Lubrication—Ball and roller bearings.* All motors fitted with ball or ball and roller bearings are despatched with the bearing housings correctly filled with grease. Under normal conditions, this is sufficient to last at least two years, provided that there is no grease leakage. The annular clearance between the shaft and bearing covers is very small, and glands for a grease seal are used, giving a bearing housing that retains the grease and rejects dust and dirt. Should the grease melt for any reason, a certain amount of leakage will occur, but provided that the correct quantity of the correct grease is used, no trouble should be experienced.

Bearing lubrication can be conveniently carried out when the motor is stripped for periodical cleaning and inspection. On motors with grease plugs or nipples, a grease gun can be used without removing the bearing covers.

(*d*) *Slip-rings and brushgear.* When maintained in good condition, slip-rings soon acquire a dark glossy surface, with complete freedom from sparking between slip-rings and brushes. Sparking at the slip-rings will speedily destroy this surface, and rapid brush and slip-ring wear will result. Periodical inspection and checking will ensure that trouble is reduced to a minimum.

The main causes of sparking at the slip-rings are: (i) excessive load (starting or running); (ii) vibration (*e.g.* from driven machine); (iii) worn brushes; (iv) sticking brushes; (v) worn slip-rings; (vi) insufficient brush pressure; (vii) incorrect grade of brush.

Starters or contactors also require some attention. Fixed and moving contacts should be maintained in a clean and unpitted condition, and any tendency to become dirty or burnt should be kept in check, and discussions with the suppliers should follow persistence of this trouble. On no account should contacts be filed indiscriminately, and only if they are badly blistered should a very fine file be used to remove the blisters and restore contact shape.

As soon as the facings have been worn away, the contacts should be replaced by a new set. It may be found desirable to remove the contactor from its housing for this purpose, and where oil type overcurrent relay dashpots are used, it is advisable to remove these to prevent the spilling of oil.

Magnet faces should be inspected periodically and kept free from rust or dirt by wiping with a clean cloth. Oil or grease should not be applied except for preservation during storage or a long idle period, and must be removed carefully before the unit is placed in service again. Should the magnet vibrate excessively during normal operation this may be due to: (i) foreign matter, for example cable trimmings, lodging on the pole face and preventing the magnet from sealing; (ii) incorrect assembly of magnets (they must always be reassembled in their original position); (iii) broken silencing rings (the ring must be completely replaced).

Power factor improvement. Before concluding this short article on electrical equipment in the dairy, something should be said on the subject of power factor correction.

Alternating current apparatus takes from the line more current than it uses. If efficiency is to be obtained, this flow of extra current must be eliminated. The ratio of useful to total current is called "power factor", and the function of power factor correction apparatus is to improve the power factor. Most Electricity Supply Authorities offer rebates to consumers who improve the efficiency of the supply system by maintaining a high power factor.

The first effect of improving the power factor of a circuit is the reduction of the current flowing through that circuit. The importance of such a reduction will be recognised immediately from the following list of secondary results: (i) reduction in kVA demand to the consumer; (ii) more power for the same kVA; (iii) less heating of cables, transformers and switch gear; (iv) improved starting torque of motors; (v) reduction in size of cables and auxiliary electrical equipment.

Meaning of Power Factor. The fundamental fact utilised in all generators and transformers of electrical energy, is the variation of magnetic flux, linking through the closed coil or loop of wire. It follows, therefore, that every piece of plant or apparatus possessing an electric winding which is fed by alternating current generates a voltage which is more or less in opposition to the supply voltage and is generally out of step or out of phase with it.

This implies also that the current flowing in most alternating current circuits is larger than is really necessary to supply the power being expended in the circuit.

The ways in which a desirable power factor can be achieved depend greatly upon circumstances. In a new installation where a favourable tariff is available, it is commendable to aim at unity power factor by installing plant which is either self-compensating or corrected by auxiliary apparatus. It is convenient to consider that the idle current required to magnetise the fields of the various induction motors is to be supplied, not by the mains, but by apparatus contained within the circuit. As it is better to prevent a condition of low power factor rather than to correct one, the plant should be so designed that induction motors, where used, should run at as high a speed as possible, and at a load approximating to their full-rated figure. It is often possible to make considerable improvements by a rearrangement of driving units alone, as the tendency is for motors to be selected of greater power than necessary, with the result that many machines are not running under the most economical conditions.

Some Corrective Apparatus. (i) *Static condensers.* A static condenser has the property of taking from a supply a charging current exactly opposite in phase to that taken to magnetise a motor. When connected in the same circuit, therefore, the idle current circulates between the motor and the condenser and is not drawn from the power supply. The latter provides the power component only when the condenser is large enough exactly to balance the magnetising component of the motor. In practice, unity power factor is not necessarily aimed at, and the motor component is only partially neutralised by the condenser. As the former varies with the load on the motor, owing to increased magnetic leakage with increased load, a fixed value of condenser capacity gives a varying power factor.

(ii) *Phase advancers.* These machines consist generally of an armature similar to that of a direct current generator, the commutator of which has brushes on it spaced at regular intervals. Three leads from the rotor of an induction motor with which the phase advancer is designed to work are taken to three or six brushes on the phase advancer commutator. The stator is sometimes left unwound, but in some cases to produce better commutation or different characteristics various types of stator windings are employed.

(iii) *Synchronous motors.* These machines were the first to be used as a means of improving power factor. The original synchronous motor was not self-starting, and was almost identical in design with an alternating current generator. Later a squirrel cage damping or amortisseur winding was fitted, and then sufficient torque was obtained to run the rotor up to speed. At full speed the excitation was switched in and the machine continued to run in synchronism. The mechanical load could then, and only then, be applied. If, due to a mechanical overload, the motor was pulled out of synchronism, it would stall, owing to the synchronising torque being considerably less than the synchronous pull-out torque.

In view of the above limitations the salient pole synchronous motor is not very widely used, although a special construction embodying an insolated starting winding built into the poles of the rotor has had a certain measure of success.

(iv) *Auto-synchronous motors.* Many attempts have been made to combine the good starting characteristic of the slip-ring induction motor with the efficiency and high power factor of the salient pole synchronous motor. It is true that the two attributes are not necessarily required in the same machine, but with the increasing interest that is now taken in reducing power costs, a synchronous machine, which is to all intents and purposes of operation an induction motor, is of considerable interest today.

It is important that, in addition to being a means of providing power factor improvement, the synchronous motor should have an electrical efficiency as high as, or higher than, that of an induction motor of equivalent output. It has already been implied that the salient pole motor has this distinction, and precautions are taken in the design of the auto-synchronous motor to ensure that the same good performance is obtained. Modern machines, when designed for unity power factor, have full load efficiencies 1 to 1½ per cent., higher than is possible with the corresponding size of induction motor.

Since the motor driving refrigeration compressor is the largest unit in the dairy, it justifies that serious consideration should be given to the application of power factor corrective apparatus, or an auto-synchronous motor.

See Management of dairies ; Refrigeration equipment; Transport.

ELECTRICAL TREATMENT OF MILK. Many attempts have been made to destroy bacteria in milk by electricity. Ordinary currents exert a lethal effect only in virtue of the heat generated, but radiation and waves of certain types can have a high bactericidal power. Beatty and Lewis (1925, *JH*, **24**, 123) considered that the heat generated was only partly responsible for the killing effect, and Prescott (1927, *AJPH*, **17**, 221) found that the effect on numbers and types destroyed was similar to that obtained with the holder method, but had an advantage in respect of cream line (the " Electropure process ").

At the present time, research on this method has been resumed and further developments may be expected shortly.

See Pasteurisation; Pasteurisation, alternatives to.

ELECTRICITY IN DAIRYING. *See* Electrical equipment.

Refs.: Brown (1940), *A Critical Study of the Application of Electricity to Agriculture and Horticulture*, London; Mitchell (1952), *Fundamentals of Technical Electricity.*

ELECTROLYTES. Any substance which, when dissolved in water, conducts electricity. Strong acids and bases (alkalis) and their salts are the best electrolytes. The conductivity of electrolytes depends not only on the degree of dissociation (p. 418) but also on the mobility of the ions or dissociated radicles, the smaller radicles having usually the greatest conductivity. The most important electrolyte in milk is salt (sodium chloride) which is responsible for about 75 per cent. of the total conductivity (p. 291).

ELECTRONICS IN DAIRYING. The term " electronics " is now used rather loosely but one aspect, that of radio-frequency waves for producing heat *inside* a material, is receiving much attention at the moment. The method has been used for drying paint, seasoning timber, and cooking. There is no inherent difficulty in producing heat inside a bulk of milk, and so pasteurising milk by electricity, but the cost at present would be prohibitive not only in plant, but also in power. The present H.T.-S.T. method (p. 790) is so cheap, efficient, and fool-proof that radio-frequency methods will have to go a long way before they can be considered as serious rivals.

See Pasteurisation, alternatives to.

Refs.: Burton (1949), *JSDT*, **2**, 75 ; Davis (1949), *D*, **66**, 321 and 367.

ELECTROPHORESIS (CATAPHORESIS). The movement of a charged particle in water under the influence of an electric current.

Refs.: Tobias *et al.* (1952), *JDS*, **35**, 1026, 1036.

ELECTROPURE PROCESS. *See* Pasteurisation, p. 819.

ELEMENT. The fundamental chemical constituents of matter, such as oxygen, carbon, nitrogen, iron, hydrogen, etc. There are 92 elements excluding those produced by radioactive mechanisms.

ELEPHANT. *See* Mammals.

EMMENTHAL. *See* Cheese, p. 291.

EMPLOYMENT IN THE DAIRY INDUSTRY. *See* Agriculture; Costings; Management; Retail.

Refs.: Mills (1953), *DI*, **18**, 126, 222; Williams.

EMULSIFIERS, EMULSIFYING AGENTS. Chemical substances or mixtures which facilitate the formation of emulsions (*see* below). Substances which help to preserve emulsions are frequently called *stabilisers* (p. 963). The two types tend to merge, but emulsifying agents such as (formerly) egg yolk or lecithin, and (at present) glyceryl monostearate (GMS) usually possess one or more hydrophilic groups (*e.g.* hydroxy) and also one or more lipophilic groups (*e.g.* stearate).

Refs.: Adam; Bushill (1951), *JRSI*, **71**, 401; Cox (1952), CI, p. 72.

EMULSION. A suspension of droplets of one liquid in another. Milk is an emulsion of fat in water (or skim milk) ; butter an " emulsion " of water in fat. The finely-divided liquid is known as the *dispersed phase* and the other as the *continuous phase.*

Refs.: Adam; Clayton; Rogers.

ENDOTOXIN. A toxin or poisonous substance which is produced by bacteria but not excreted by them. Thus, the bacteria themselves can cause a reaction but not the culture medium or the food in which they have been growing. *See* Food poisoning.

ENERGY VALUES. The energy value of a food is usually expressed in terms of *calories* per g., *i.e.* the amount of heat which would be produced if 1 g. of the food were completely burnt or oxidised to carbon dioxide and water. Fat has easily the highest energy value, being about 2¼ times as efficient in this respect as carbohydrates (starches and sugars) and proteins.

Fat	*c.* 900 Cals. per 100 g.
Carbohydrate	*c.* 400 Cals. per 100 g.
Protein	*c.* 400 Cals. per 100 g.

The energy value of milk *solids* is high because these consist of about 30 per cent. fat, 40 per cent. sugar, and 25 per cent. protein. (Minerals or salts have no energy value as such.) Butter is one of the best energy sources known and cheese and milk powder are also extremely good. Condensed milk is also valuable as the added sugar increases the calorific value; evaporated milk has a lower energy value and milk is relatively poor on account of the large amount of water it contains (*c.* 87·5 per cent.). *See* Calories; Economic nutritional values; Nutritive value.

ENGINEERING, DAIRY. *See* various headings.

Refs.: Cuttell; Enock; Farrall; Hill; Sandelin (1929), *Dairy Engineering* (in Finnish), Helsinki; Zimmerman and Lavine (1952), *Chemical Engineering Costs.*

ENTERIC FEVER. The common name for typhoid fever. *See* Classification; Diseases; *Eberthella.*

ENTERITIS. Inflammation of the intestine, usually accompanied by pain, fever, and diarrhoea. *See* Food poisoning.

ENTEROCOCCUS. The old name for *Str. faecalis* and its variants. *See* Classification; Lactic acid bacteria.

ENTRAINMENT. The carrying-over of a liquid in the form of spray in a moving gas, as in the evaporation or condensing of milk (p. 280).

ENTROPY. The Second Law of Thermodynamics (*q.v.*) states that heat does not spontaneously pass from a cold body to a less cold body. Expressed otherwise, this means that the free energy of systems tends to run down, energy differences tend to level out and the " degree of mixed-upness " tends to increase. This last concept is scientifically defined as Entropy, though it is changes in entropy with which physicists are generally concerned. If, in a reversible change, a substance takes in a small quantity of heat dQ at a temperature T (absolute scale) the increase in entropy is defined as dQ/T.

ENZYMES. Enzymes are substances produced by living organisms which display the chemical property of *catalysis*, *i.e.* they specifically accelerate particular chemical reactions. Like the hormones and most of the vitamins they need to be present only in very small concentrations, and they exert their action without themselves being used up in the process. It is by means of enzymes that animals, plants, and microbes are able to transform or " metabolise " substances in a rapid and efficient sequence of reactions—for instance, the oxidation of foodstuffs into carbon dioxide and water with the liberation of energy. Such an oxidation can, of course, be brought about in the test tube without the help of enzymes, but only by employing strong reagents or temperatures which would be incompatible with life.

The word " enzyme " is derived from Greek words meaning " in yeast ", recalling the epoch-making discovery by the Buchner brothers in 1897 that a cell-free extract made from yeast would catalyse the fermentation of sugar, yielding alcohol and CO_2, a process formerly believed to be characteristic of the intact living cell. Other enzymes, although formed inside cells, are found naturally outside them, in secretory fluids; and those of the digestive juices, whereby foods are broken down and rendered soluble, have long been known. During this century, however, following the example of Buchner, many hundreds of enzymes have been separated from all kinds of cells, so that it is now known that almost all the chemistry of life is dependent on enzymes. It is obvious that a knowledge of enzymes is assuming ever more value in the understanding of all kinds of biological problems; with this in mind, as well as a number of applications of enzymology directly bound up with milk technology, we turn to a brief review of the general properties of enzymes.

Classification. Enzymes may be classified according to the type of reaction catalysed, the most important being: (i) *Hydrolysing enzymes,* including the digestive enzymes and many others, all breaking down larger molecules to smaller ones by hydrolytic cleavage. (ii) *Phosphorolysing enzymes* resemble class 1, but they effect cleavage of large molecules by introducing a molecule of phosphoric acid instead of one of water. They therefore require the presence of phosphate ions. This type of reaction is more freely reversible than hydrolysis, and is of great importance in synthetic processes, *e.g.*

$$\text{Glycogen} + \text{phosphoric acid} \rightleftharpoons \text{glucose-l-phosphoric-acid-ester.}$$

(iii) *Oxidising enzymes* include all those responsible for making available the energy of combustion of the foodstuffs. Biological oxidation is a step-wise process, so that many enzymes are needed. At one end of the chain, the cytochromes react with the oxygen which is carried to the tissues by the blood. At the other end the primary foodstuffs are acted on by dehydrogenases, of which a large number are known. The hydrogen so mobilised is passed through a series of carrier enzymes, eventually to react with oxygen.

Other important classes which can only be mentioned are transferring, isomerising, and adding enzymes.

The *Names* of enzymes serve as a further classification, since they are usually formed from the name of the substrate together with the suffix -ase. Thus:

Phosphatase acts on organic phosphates.
Lipase acts on fats (lipoids).
Amylase acts on starch (amylum).
Succinic dehydrogenase acts on succinic acid.

Properties of Enzymes. In 1926 Sumner succeeded in crystallising urease, and since that date several other enzymes have been isolated in the crystalline state. In each of these cases it has been shown that the crystals consist wholly of protein, or are mainly protein with an active prosthetic group. A considerable bulk of evidence exists indicating that many of those enzymes which have not yet been purified are also largely protein. It is not clear whether it is the protein itself which acts as the enzyme, or whether the protein merely acts as a colloidal carrier for an active grouping, but so far, all enzymes studied have been shown to form colloidal solutions, to have high molecular weights and to be thermolabile. It is generally agreed, however, that the site of enzymatic activity is probably only at discrete spots on the surface of the molecule. Some enzymes are secreted in an inactive form, as pro-enzymes, in which, it is believed, the active spots are covered and rendered inaccessible. The activation of these pro-enzymes is analogous to a process of " unmasking " in which the polypeptide " mask " is removed by the action of proteolytic kinases. A typical example of this type of action is the transformation of trypsinogen to its active form, trypsin, by enterokinase after the inactive enzyme has entered the small intestine. The fact that several of the powerful proteinases are known to exist in the inactive " masked " form in the cells has led to the view that this is a device by which the cells are protected from the action of the enzymes they elaborate.

It was early established that in addition to the non-diffusible protein fraction, many enzymes required the presence of substances which were of low molecular weight and dialysable. The compounds in this group, called co-enzymes, vary in complexity from simple inorganic ions to such complex compounds as adenine-nicotinic amide dinucleotide (co-enzyme I).

A characteristic property of enzymes is their specificity. Practically all enzymes exhibit stereochemical specificity ; *e.g.* enzymes of animal origin will only act on the naturally occurring D-sugars and will leave unaffected the L-sugars. In addition to this configurational specificity, enzymes show varying degrees of selectivity toward their substrates. Thus, there are enzymes of low specificity, *e.g.* pepsin and trypsin, which will attack a particular form of linkage. There also exist enzymes such as arginase in which the specificity is such that the enzyme will act only on a very limited group of closely related compounds.

Enzymes normally act over a very restricted *p*H range, and usually exhibit well-defined *p*H optima, or points of maximum activity. In general the *p*H optimum is a characteristic of the enzyme, but several have been shown to possess *p*H optima which vary distinctly with the nature of the substrate, the *p*H optimum of pepsin, for instance, varying between 1·5 and 2·5 with different protein substances. For the majority of enzymes the *p*H optimum falls in the range of *p*H 5·0 to 7·0 and represents not only the point of maximal activity but also of maximum stability. At *p*H levels far removed from the optimum, both on the acid and alkaline side, most enzymes are irreversibly inactivated. No information is available on the state of activity within the cell of those enzymes which have very alkaline *p*H optima (*e.g.* arginase and alkaline phosphatase). It seems possible that there might exist localised points in the cell, possibly on colloidal surfaces, which are sufficiently alkaline to enable these enzymes to work at velocities approaching their maximum. This must almost certainly be the case for alkaline phosphatase which has a *p*H optimum of 10·0 and which has been shown to be almost inactive at *p*H 7·3, the generally accepted value for the cell *p*H.

Like most chemical processes the velocity of an enzyme reaction is increased by a rise in temperature. At high temperatures, however, thermal inactivation of the enzyme, presumably due to the denaturation of the protein moiety, acts in a reverse direction. There exists, therefore, an optimum temperature at which the velocity of the reaction is maximal, this temperature usually being of the order of 45° to 55° C. At temperatures of 80° C. and above most enzymes undergo irreversible destruction.

The Michaelis and Menten theory of enzyme action postulates a combination of the enzyme with its substrate to form an intermediate compound which then breaks down to give the enzyme and end product. According to this theory, the velocity of the reaction is governed by the rate at which the enzyme combines with its substrate and the rate at which the intermediate compound decomposes. The rate of combination of the enzyme and substrate is directly related to the substrate concentration. With most enzymes the velocity of reaction increases with increasing substrate concentration up to a limiting maximum at which the enzyme is fully saturated with its substrate, the curve expressing this relationship being a rectangular hyperbola. The substrate concentration which will give a velocity one half of the maximum velocity attainable is known as the Michaelis constant (Km) and is said to be characteristic for each enzyme. Many enzymes are inhibited by high substrate concentrations and these do not exhibit the Michaelis-Menten curve but have a substrate concentration optimum.

Theoretically, all enzyme reactions are dynamic equilibria, the velocity of the reaction in either direction being dependent on the concentration of the reactants. Since the reactions are reversible the accumulation of end products tends to reduce the apparent rate of the reaction.

Enzymes of the Mammary Gland. Almost all synthetic reactions in the body are catalysed by enzymes. The mammary gland during milk secretion is a site of intense synthetic activity and it may be presumed that the synthesis of the varied milk constituents is a process which requires the presence of a great variety of enzymes. Some of these enzymes will be primarily concerned with the production of energy to be used either for synthetic work, such as the manufacture of substances like lactose, milk protein or the milk fatty acids, or in physical chemical work such as absorption or secretion across membranes against a concentration gradient. Other enzymes will be concerned in the actual manufacture of specific milk substances.

Knowledge of the enzyme systems operating in the mammary gland is very incomplete and only a few have been investigated systematically in a quantitative way. Among the enzymes found in the mammary gland are many of the enzymes of the Krebs' tricarboxylic acid cycle, a fatty acid oxidase, acid and alkaline phosphatase, amylase, maltase, lipase, arginase, xanthine oxidase, glutamic-aspartic transaminase, glutamic dehydrogenase, β-glucuronidase, cathepsin, 6-phosphogluconic acid dehydrogenase and glucose-6-phosphate dehydrogenase.

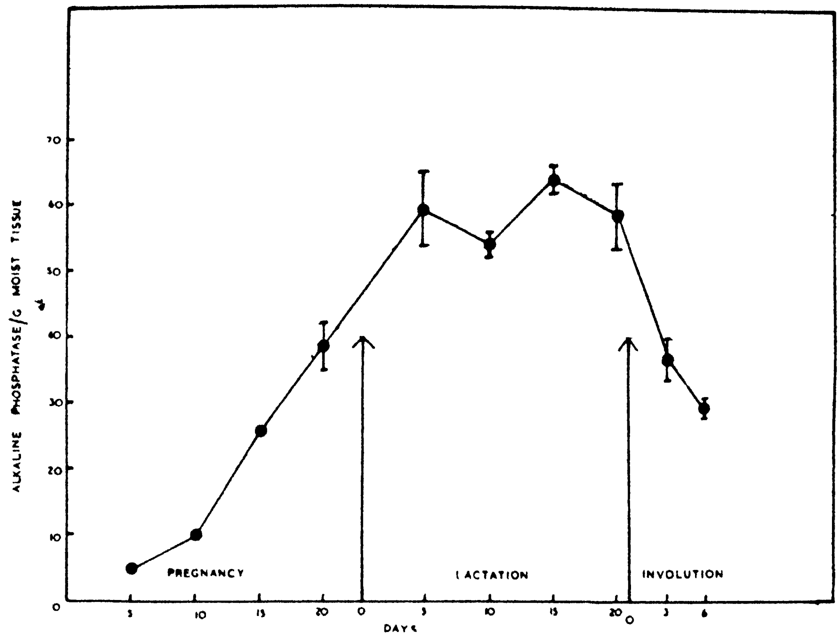

FIG. En 1.—*Graph of Mammary Enzymes (alkaline phosphatase). Variations in the mammary gland alkaline phosphatase. The vertical lines are equal to twice the S.E.M. (Folley and Greenbaum,* 1947).

Many of these enzymes have not been studied in detail and it is possible that some of those listed may, in fact, be mixtures of several related enzymes. Lipase, for instance, has been shown to contain a diacetinase in addition to the usual triacetinase.

The presence of an active tricarboxylic acid cycle was foreshadowed by Folley and French who showed an eight-fold increase in respiration corresponding to the eight-fold increase in milk secretion in the rat over the 20-day period of lactation. The presence of most of the enzymes of the tricarboxylic acid cycle has been confirmed by Moore and Nelson (1952). The mammary gland, therefore, possesses the normal machinery for the production of energy.

Enzymes that have been studied systematically throughout the whole period of pregnancy, lactation and mammary involution are alkaline phosphatase (Fig. En 1) and arginase (Folley and Greenbaum. 1947), succinic dehydrogenase and cytochrome oxidase (Moore and Nelson, 1952), glutamic-aspartic transaminase, glutamic dehydrogenase, β-glucuronidase and cathepsin (Greenbaum and Greenwood, 1954) and glucose-6-phosphate and 6-phosphogluconate dehydrogenases (Glock and McLean, 1954). From a study of the results on those of the ten enzymes studied which are situated on the mitochondria two main patterns seem to emerge. The first, typified by succinic dehydrogenase, shows a low level of enzyme during pregnancy, an abrupt rise in the activity of the enzyme at parturition, the maintenance of a high, but reasonably constant, level of activity throughout lactation and an abrupt fall in involution. The enzymes which give this " plateau " type of curve, cytochrome oxidase, succinic dehydrogenase and glutamic dehydrogenase could well be enzymes primarily concerned with the energy metabolism of the gland. The second type of curve, typified by arginase (Fig. En 2), shows a slow but progressive rise from the inception of pregnancy to weaning. It could well be that the enzymes which show this latter pattern, arginase and cathepsin, are primarily concerned with the production of intermediates required for the synthesis of milk constituents and appear to be closely related to the secretory activity of the gland.

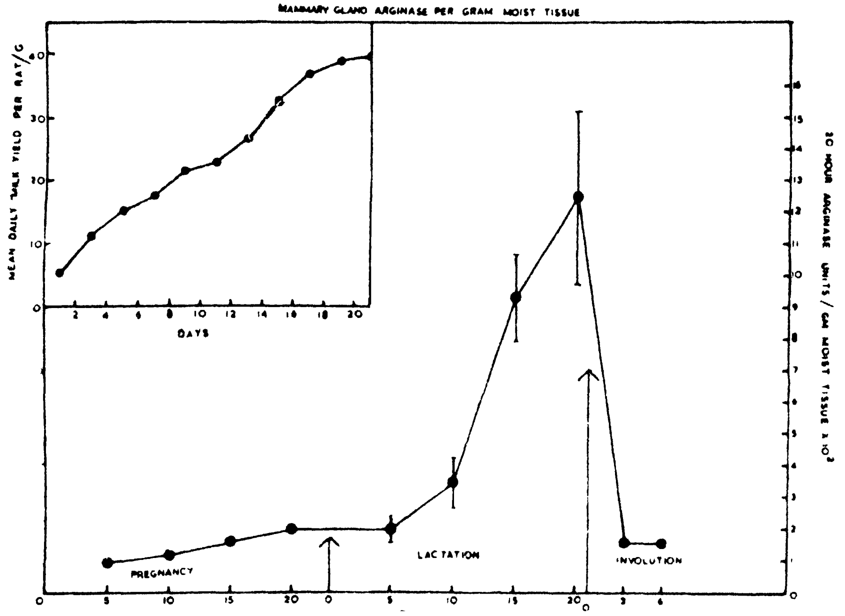

FIG. En 2.—*Graph of Mammary Enzymes (arginase). Variations in mammary gland arginase. The vertical lines are equal to twice the S.E.M. The inset represents the lactation curve of the rat. The figure illustrates the dramatic increase in the enzyme content of the gland in response to increased requirements for materials necessary for the expanding milk production (Folley and Greenbaum, 1947).*

The most dramatic changes so far measured are those of the enzymes of the direct oxidative pathway (Glock and McLean, 1954). Glucose-6-phosphate dehydrogenase increases 60 fold in lactation and 6-phosphogluconate dehydrogenase 20 fold. The function of these enzymes is not clearly understood but may be related to the nucleic acid metabolism of the gland. The tremendous increase in activity of these two enzymes clearly indicates that they play an important part in the economy of the mammary gland, although our understanding of their role must await further fundamental research.

Enzymes of Milk. The enzymic constituents of milk may appear as something of an anomaly, for no definite function is known for any of them. It is probable that they escape into the milk from the cells of the mammae during secretion, or filter through from the blood, and are without significance for the suckling young. However, these enzymes assume importance in relation to the handling of milk in industry. This practical aspect of the milk enzymes can be considered under two heads : their effect on the major milk constituents during storage ; and the use made of the heat-susceptibility of enzymes as a test for heated milk. Most studies on the enzymology of milk have been made with substrates foreign to milk, which happen to be most suitable for the purpose of experiment, *e.g.* the phenyl phosphate used in studies of phosphatase activity. The alkaline phosphatase has been investigated very thoroughly ; information on the factors influencing its activity in milk may be found in the paper of Folley and Kay (1936).

Action of Milk Enzymes and the Development of Taints. Under certain conditions milk enzymes may cause chemical alteration of the protein or especially the fat, to a degree sufficient to spoil the flavour. It must be emphasised, however, that the native enzymes are of secondary importance, as far as keeping qualities are concerned, compared with contaminating micro-organisms. These, with their amazing powers of multiplication can quickly overshadow the native enzymes in chemical activity, and the major problem of storage is to control their growth. It is true, nevertheless, that the effects of organisms are due to their own enzymes, *e.g.* the formation of the acids of sour milk, a typical fermentation. In the present section it is the native enzymes alone that concern us.

Lipase. There are several distinct fat-splitting enzymes in milk. In whole milk their action is only detectable under certain conditions. Micro-organisms promote acidity which inhibits lipase. Hygienically treated milk, kept for some time without contamination, is therefore most prone to undergo lipolysis. There is more lipase in winter than in summer milk, and at least one of the lipases is inhibited by sunlight. They do not withstand pasteurisation. Lipase may be active in butter made from unpasteurised sweet cream, and in cream stored at winter temperature so that no acid is formed. Conditions such as homogenisation which bring fat and enzymes into close contact increase activity. By the action of lipase on fat, fatty acid is set free. The presence of volatile fatty acids in butterfat is responsible for the characteristic rancid taint of butter :

$$\text{Tributyrin} \xrightarrow[\text{lipase}]{H_2O} \text{Butyric acid} + \text{glycerol.}$$

In whole milk a bitter flavour is produced. Bitter milk may be given by particular cows in late lactation, when lipase content may be abnormally high.

Peroxidase. This enzyme catalyses the oxidation of a variety of organic substrates by means of hydrogen peroxide. It is a heme-containing protein with an iron content of 0·07 per cent. It has been crystallised by Theorell. Hydrogen peroxide is not normally found in milk, although it may occur as a result of catalytic action of metals such as copper. Under such conditions the peroxidase may play a part in the occurrence of " oxidised " flavours (*q.v.*), but the metal catalyst is much more important in this respect. For the demonstration of peroxidase activity, *see* under *heat inactivation.*

Xanthine-aldehyde oxidase. This is a flavoprotein catalysing the direct activation of oxygen in the oxidation of a number of purines, and a wide range of aldehydes. The latter action was formerly attributed to a distinct " Schardinger enzyme ", but it now appears that the same protein carries two reacting groups.

$$\text{Hypoxanthine} \xrightarrow{\frac{1}{2}O_2} \text{Xanthine} \xrightarrow{\frac{1}{2}O_2} \text{Uric acid}$$

$$\text{Acetaldehyde} \xrightarrow{\frac{1}{2}O_2} \text{Acetic acid.}$$

The oxidase can also act with reducible dyes such as methylene blue in place of oxygen. It would not appear to be of significance in practice, except that a distinction must be drawn between the reduction of dyes by this enzyme in milk, *if an aldehyde is added*, and the reduction of the dyes by bacteria, using the milk solids as substrates, which is the basis of the reduction tests for milk quality.

Proteinase. A casein-hydrolysing enzyme, sometimes called galactase (a bad name) may be of significance in cheese manufacture. It is active at an alkaline *p*H, and is said to resemble trypsin.

Lactase. The power of milk to hydrolyse lactose is at best feeble. The fermentation of mare's milk, yielding "koumiss" is achieved by the help of a special yeast which contains lactase. It is analogous to the common alcoholic fermentation.

The Heat Inactivation of Enzymes. ***Tests for heated milk.*** The introduction of legal requirements for pasteurisation called for suitable tests for heat treatment of milk. The heat labile enzymes, rendered inactive if adequately heated, furnished the basis for such tests. The present reliable *phosphatase* test (*q.v.*) depends on the constant presence of the enzyme in untreated milk, the standardisation of methods for its detection, and the parallel between the destruction of the enzyme and of harmful organisms (Kay and Graham, 1935).

One of the earlier methods depended on the Storch test for *peroxidase* activity. Hydrogen peroxide and paraphenylenediamine are added to the milk sample. In the presence of active enzyme, a blue colour is seen, due to the oxidation of the base.

A test based on the *amylase* reaction (hydrolysis of starch) is another possibility. As described by Gould (1932) this method appears to give a very sensitive test for the presence of raw milk.

Other Enzymes with Applications in Dairying. *Rennin.* "Rennet" is a preparation made from the fourth stomach (abomasum) of young calves. When added to milk at 25° to 35° C. it brings about a coagulation of the milk protein, forming a curd or junket. "Rennin" is the name applied to the active principal. It has been crystallised by Berridge (1945) and appears to be a protein, although there have been reports of a highly active nitrogen free rennin. Berridge considers that these may indicate the existence of a "prosthetic group" with independent activity.

Rennin is a proteolytic enzyme of the cathepsin type with a *p*H optimum of 3·7 when haemoglobin is the substrate and possibly a little higher when casein is substrate. The chemical reaction catalysed by rennin in milk coagulation is the transformation of casein to paracasein, a substance which is easily denatured by heat and becomes insoluble in the presence of calcium ions. This proteolysis is very limited in extent and resembles somewhat that found in partial heat inactivation of casein. No free amino acids are formed in the reaction which apparently consists of an unfolding and breaking of the peptide chain of γ-casein to yield several large polypeptides. It is possible that under the acid conditions occurring in cheese the hydrolysis of the casein curd is carried to a further stage and contributes to the development of the ripeness in the cheese.

Pepsin is the chief proteinase of the mammalian stomach. Like rennin it may be used to coagulate milk, but it acts at a more acid *p*H, 1·5 to 2·0. Its hydrolytic action also requires more careful control since the enzyme is more powerful in its action than rennin and can cause a greater degree of hydrolysis of the casein molecule to free amino acids. Its specificity is such that, on the peptides tested, it will only act on the peptide link involving the amino group of an aromatic amino acid.

Trypsin is the chief proteolytic enzyme of the small intestine. It is produced in the pancreas and has an alkaline *p*H optimum around 8. Its action on casein resembles pepsin, the point of attack in the case of trypsin being at the peptide link involving the carboxyl group of a basic amino acid. Tryptic digests of casein have been used as nutritive media in bacteriology. *See* Media p. 465; Phosphatase; Rennet.

Refs.: (1) Nord (ed.), *Advances in Enzymology; General Properties of Enzymes.* Haldane (1930), *Enzymes*, London; Oppenheimer (1938), *Die Fermente und ihre Wirkungen*, The Hague; Sumner and Somers (1947), *Chemistry and Methods of Enzymes*, 2nd ed., New York. (2) *Enzymes in Metabolism.* Baldwin (1952), *Dynamic Aspects of Biochemistry*, Cambridge. (3) *Enzymes of the Mammary Gland.* Moore and Nelson (1952), *Arch. Biochem. Biophys.*, **36**, 178; Greenbaum and Greenwood (1954), *Biochem. J.*, **56**, 625; Glock and McLean (1954), *Biochem. J.*, **56**, 171; Folley and Greenbaum (1947), *Biochem. J.*, **41**, 261. (4) *Enzymes of Milk.* Richmond; Rogers; Davies; Folley and Kay (1936), *Enzymologia*, **1**, 48; Polis and Shumuker (1950), *JDS*, **33**, 619 (adolase); Kay and Graham Jnr. (1935), *JDR*, **6**, 191; Gould (1932), *JDS*, **15**, 230. (5) *Rennin*, Berridge (1943), *FM*, **18**, 305; (1945), *BJ*, **39**, 179.

ERGOSTEROL. A sterol which is activated by sunlight to become vitamin D (D_2). *See* Vitamins.

ERROR. *See* Accuracy; Laboratory; Statistical formulae.

ERRORS IN SAMPLING. It should be regarded as axiomatic that no analysis is worth having unless the sampling is above reproach. In dairying, sampling is sometimes faulty due to failure to mix the fat thoroughly. Thus the fat values may be high (or low) but such imperfect mixing has much less effect on the solids-not-fat and none on the freezing-point.

Bacteriologically it is more important to observe aseptic precautions than to mix the milk thoroughly even though the fat globules may have 90 to 95 per cent. of the bacteria attached to them.

The surface portions of milk products, *e.g.* butter and cheese, may have quite a different flora from the interior and should be sampled separately. *See* Accuracy; Routine tests; Sampling; Testing of milk supplies.

ERUCIC ACID OR 13-DOCOSENOIC ACID. One of the rare unsaturated fatty acids found in the fat of milk of cows fed on rape oil. Its formula is

$$C_{11}H_{23}CH = CH \,.\, C_8H_{16} \,.\, COOH$$

See Fatty acids.

ESCHERICHIA. The genus of true coli bacteria. *See* Classification; Coliforms.

ESSENTIAL OIL FLAVOURS. The milk of cows which have fed on plants containing essential oils such as garlic, thyme, mint, and chamomile, may contain so much of the characteristic flavour that it is unusable and may be rejected by the buyer, although there is no effect on keeping quality. *See* Flavours; Taints.

ESTERS. Esters may be considered as the salts of organic chemistry, *e.g.*

$$\underset{\substack{\text{sodium}\\\text{hydroxide}}}{NaOH} + \underset{\substack{\text{hydrochloric}\\\text{acid}}}{HCl} \rightarrow \underset{\substack{\text{sodium}\\\text{chloride}}}{NaCl} + H_2O$$

$$\underset{\text{ethyl alcohol}}{C_2H_5 \,.\, OH} + \underset{\text{butyric acid}}{C_3H_7 \,.\, COOH} \rightarrow \underset{\text{ethyl butyrate}}{C_2H_5 \,.\, O \,.\, CO \,.\, C_3H_7}$$

$$\underset{\text{glycerol}}{C_3H_5 \,.\, (OH)_3} + \underset{\text{palmitic acid}}{3\,C_{15} \,.\, H_{31} \,.\, COOH} \rightarrow \underset{\substack{\text{glyceryl tripalmitate}\\\text{(one of the chief constituents}\\\text{of butter fat)}}}{C_3H_5(O \,.\, CO \,.\, C_{15}H_{31})_3}$$

EUTECTIC MIXTURE. A mixture of substances which, although not forming a compound, shows a sharp melting-point which corresponds to the minimum temperature obtainable. Also called a cryohydrate. *See* Freezing-point.

EUTECTIC TEMPERATURE. That temperature at which a eutectic mixture solidifies.

EVAPORATION. The changing of liquid into gas. Considerable energy or heat is needed for this, to free the molecules from the liquid phase. This energy is the *latent heat of evaporation* and is recovered when the vapour or gas recondenses. *See* Condensed and evaporated milk ; Steam.

Refs.: Badger and McCabe ; Farrall ; Hausbrand (1933), *Evaporating, Cooling, and Condensing Apparatus*, London.

EVENING MILK. This is usually less in quantity but richer in fat than morning milk, due to the shorter period between milkings. *See* Collin's rule ; Composition, factors affecting.

EWE MILK. *See* Mammals.

EXOTOXIN. A toxin or poisonous substance excreted by bacteria into the culture medium or food. Such food may be dangerous after the bacteria have been removed or died. *See* Food poisoning.

EXPANSION. Most materials expand on heating and contract on cooling, and this factor must be considered not only in designing plant and containers, but also in measuring, especially volumes of liquids. Water expands on freezing. Milk behaves almost exactly as water in this respect, *i.e.* it expands about 1 part per thousand for every 5° C. or 9° F. rise in temperature, and contracts a similar amount on cooling. When correcting for temperature, allowance must be made for the change in volume of the containing vessel which is usually about ⅓ or ¼ of that of the liquid. Thermal expansion is a factor to be considered with glass pipelines. *See* Thermal expansion.

EYES IN CHEESE. Holes produced by the propionic acid fermentation (p. 857). *See* Emmenthal Cheese p. 192.

F

FACULTATIVE. A term, when applied to micro-organisms, indicating that they are capable of living under more than one condition, *e.g.* with or without air. *See* Aerobic; Classification.

FAECES, BOVINE, EFFECT ON KEEPING QUALITY OF MILK. The early work on clean milk production laid considerable emphasis on manurial contamination and the effect of coli on keeping quality. This outlook tended to dominate all advisory work, and poor keeping quality and positive coli results were usually attributed to careless milking allowing dung to gain access to the milk. Actually, fresh dung has very little effect on the keeping quality of milk and may even improve it. Whether this is due to bacteriophages or other bactericidal factors is not known.

FALL. The angle of a floor to the horizontal. A dairy floor should have a fall of at least 1 in 50 to permit efficient washing down. *See* Design of dairies; Floors.

FALLACIES IN DAIRYING. There are a number of fallacies or false beliefs held by "practical men" in the dairy industry or the general public. Some of the more general and technically interesting are briefly reviewed below.

(*a*) *High fat milk will not keep as well as milk of ordinary fat content on account of the high fat content.* There is no experimental evidence to support this. Factors in the supposition may be the lack of need for good keeping quality in high fat milk destined for butter making, and possibly the greater difficulty of cleaning churns, etc., which were used for such milk.

(*b*) *The acidity test is a reliable measure of souring.* Titratable acidity measures the casein, acid salts, and carbon dioxide in milk (average 0·14 per cent. as lactic acid); only increases *above* this initial value are a reliable measure of souring. *See* Acidity.

(*c*) *Feeding watery food will increase the proportion of water in the milk or increase the yield.* This supposition is not supported by any experimental evidence. *See* Freezing point test.

(*d*) *Adverse conditions such as bomb shock, poor quality feeds, bad weather, excitement, etc., can affect the freezing-point, and so explain the allegation of added water by the analyst.* All the evidence is against this claim. (Rowland (1941), *A*, **66**, 327.)

(*e*) *Taints of well-defined bacteriological origin are due to cows feeding in a certain field, on a certain ration, etc.* Usually the fault can be traced to dirty utensils. The field theory is sometimes right because the cows have been drinking in a certain pond and their udders may become infected.

(*f*) *Refrigeration of milk below a certain temperature, e.g. 38° F. results in a reduced keeping quality; also milk cooled to below 38° F. will get warm more rapidly than if cooled only to 38° F.* There is no scientific evidence for this; in practice there is no need to cool below 38° F. except in very hot weather when usually it cannot be done.

(*g*) *Thunder causes milk to "turn".* There is no scientific evidence for this; thunder is usually preceded by a sudden rise in temperature which is probably the true cause.

(*h*) *Milk powder was reconstituted during the war and sold as liquid milk.* This belief arose because lumps of solid milk were sometimes found on the surface of the milk. Such lumps are usually due to sweet curdling (p. 1002) which is more common in pasteurised milk than raw. It would be dangerous to reconstitute milk powder in this way without special precautions.

(*i*) *Plant can be sterilised by turning a steam hose on to it.* This is a lazy way and is of little use, although the clouds of steam and noise may be impressive. It may even do more harm than good by warming up the bacteria inside imperfectly cleaned equipment. *See* Cleaning and sterilising.

(*j*) *It is illegal to take samples of milk on Sunday for fat testing.* This idea is prevalent in some rural districts. Comment is unnecessary.

(*k*) *Milk sold in cities is of constant composition because the big companies standardise the milk* (*i.e. remove fat to reduce it to a constant amount*). It would seem unnecessary to deny this, were it not for the fact that persons holding responsible positions still assert it. Not only is it quite untrue but obviously it could not be done without a properly organised method of separating part of the milk and disposing of the cream.

(*l*) *Pasteurisation cannot be relied upon to kill T.B.* In the early days of pasteurisation this may have been true. However, there is no reason now to doubt the efficacy of efficient pasteurisation in this respect. No authentic case of the survival of T.B. in properly pasteurised milk has ever been proved. (*See* Pasteurisation.)

FARM ADVISORY WORK. In the dairying sense this term usually refers to advice given to farmers and their milkers about clean milk production (p. 241). The problem is more psychological than scientific in that the cause of the trouble, *e.g.* unclean utensils, lack of cooling, etc., is usually easy to locate, but persuading the farmer or his staff to take the proper precautions is often a difficult matter. The method of approach is of first importance ; a rather ignorant instructor with the right manner may do more than a highly educated person who is too " high brow " or fails to gain the farmer's confidence.

Farm advisory work may be considered under four headings : (i) psychological study of the type of farmer and staff ; (ii) location of fault ; (iii) convincing the farmer that this fault is the cause of his trouble ; (iv) ensuring that the fault is remedied, and the necessary " follow up " work.

The first visit should concentrate on establishing a friendly relationship, sizing up the farm and its staff and locating the more serious causes of trouble. The laboratory record of the farm should be studied immediately before the visit, and some time after the visit, and the essential observations recorded on a form. On no account should any form or notebook be produced in the presence of the farmer. The adviser should comment freely on the good points and make a mental note of the bad, only discussing the latter on a first visit in a very cautious way. Should the farmer invite comment the faulty matters may be discussed in detail, but generally it is better to observe and take samples of the milk at different points and rinsings of the utensils, if this is possible. Farmers are accustomed to such tests and usually make no objection to the taking of such samples. It is most important, however, to give the farmer the results, if possible personally so that their significance can be discussed, but otherwise by letter in which case the comments should be written in simple language. The greatest scientific truths can be stated in simple words.

Practical demonstrations of milking methods are often valuable but these have sometimes " put the backs up " of the milking staff, implying that they do not know their job. It may be wiser to drop a hint but one cannot dogmatise on this point. *See* Agriculture; Clean milk production and distribution; Clean milk production, the relative importance of various factors; Cooling milk; Dairy farm buildings; Flavours; Taints; Testing of milk supplies.

Refs.. Min. Agric. (1932), *Bulletin* 46 (tests) ; McKenzie and Bowie (1946), *SAB*, p. 35.

FARM BUILDINGS. *See* Dairy farm buildings.

FARMING. *See* Agriculture; Breeding; Dairy farm buildings; Feeding; Management of cattle; Pigs.

FAT. Fat is chemically a mixture of glycerides of fatty acids (p. 462), and physically is characterised by its insolubility and non-miscibility with water, but solubility in ether and similar solvents. Fat is fairly stable and has the highest calorific value of all foods, about 2¼ times that of protein and carbohydrates or sugars. Milk fat always contains small amounts of cholesterol, the yellow-red carotene, and traces of fatty acids resulting from the splitting of the glycerides by lipase (*see* Enzymes). In addition, the fat-soluble vitamins A and D are present in the fat phase.

The glycerides in milk fat are all of the even-numbered carbon atom variety (*see* Constituents and Fatty acids) and the high proportion of the lower acids C_4 to C_{10} is one of the most characteristic features of butterfat, and for this reason it gives high Reichert-Meissl values (p. 901). Milk fat also contains the unsaturated acids oleic and linoleic, which are the first to be liberated by some lipases, and which are highly reactive to some oxidising systems, resulting in rancidity and oxidised flavours, and give a high iodine value.

Refs.: Williams, K. A.; Davies; Richmond; Rogers; Hilditch; Mulder (1947), *Problems and Results of Dairy Research*, Vol. I, "The Fat in Milk", The Hague; Bailey (1950), *Melting and Solidification of Fats and Fatty Acids*, N.Y.; Deuel (1951), *The Lipids ;* B.S. 684 (1950) (Methods of Analysis); B.S. 627 (1953) (Sampling).

FAT, DETERIORATION OF. *See* Auto-oxidation; Catalysts; Copper; Flavours; Rancidity.

FAT IN MILK, DETERMINATION OF. Babcock Method. *Apparatus required.* Babcock bottles ; 17·6 ml. Babcock pipette ; Automatic 17·5 ml. acid measuring device ; Babcock centrifuge ; Calipers or dividers for measuring the fat column ; Bath at 135° to 140° F. with rack.

In addition, it is helpful to have a speed indicator for the centrifuge and a mechanical shaker for the Babcock bottles.

Reagent. Sulphuric acid sp. gr. 1·82 to 1·83 at 68° F.

Treatment of sample (for both Babcock and Gerber tests). Warm to 60° to 70° F. and mix thoroughly, preferably by pouring it backwards and forwards into a clean, dry vessel. If marked separation of fat has occurred, warm to 100° F., mix well and cool to 70° F. with occasional agitation.

Procedure for Babcock test. Transfer 17·6 ml. of milk to the Babcock bottle and then add 17·5 ml. of sulphuric acid sp. gr. 1·82 to 1·83, allowing the acid to flow slowly down the neck of the bottle and revolving the latter. Mix acid and milk by a gentle rotary motion or in the mechanical mixer. Next place the bottles in the centrifuge, balance the load and centrifuge for 5 min. at the recommended speed (from 690 to 1050 r.p.m. according to the diameter of the centrifuge).

Soft water is added at a temperature of 135° to 140° F. to bring the contents to the lower end of the neck. Centrifuge again for 2 min., add water to bring the level to near the top of the graduated portion. Centrifuge again for 1 min. and immerse the bottles in a water bath at 135° to 140° F. Leave for 3 min. and then remove the bottles one at a time and read the height of the fat column with dividers, measuring from the lowest point of the bottom meniscus to the highest point of the top.

***Hints on performing test*: *likely causes of faults*.** (1) *Fat column too dark or showing dark specks.* (*a*) Too much acid. (*b*) Acid too strong. (*c*) Acid poured directly into milk instead of down side of bottle. (*d*) Acid and/or milk too warm. (*e*) Failure to mix milk and acid promptly.

(2) *Fat column too light or showing light specks.* (*a*) Too little acid. (*b*) Acid too weak. (*c*) Acid and/or milk too cold. (*d*) Curd not dissolved before centrifuging.

Gerber Test. *Apparatus.* Standard Gerber butyrometers ; Rubber stoppers ; 11 ml. pipette for milk ; 10 ml. pipette (or automatic measure) for acid ; 1 ml. pipette (or automatic measure) for amyl alcohol ; Stand for shaking butyrometers ; Centrifuge working at 1100 r.p.m. and 18 to 20 in. in diameter ; Water bath.

Reagents. Sulphuric acid sp. gr. 1·815 at 68° F. ; Amyl alcohol.

Procedure. Treat the sample as previously described. Add 10 ml. sulphuric acid to the butyrometer without wetting the neck. Similarly add 11 ml. of milk and 1 ml. of amyl alcohol. Then firmly insert the rubber stopper and shake the butyrometer carefully until the curd is dissolved and no white particles can be seen. Place in a water bath at 68° C., stopper downwards, and keep there until a set is ready for centrifuging. Spin for 4 to 5 min. at 1100 r.p.m., making sure first that the fat column is on the scale. Then place in the water bath for 3 min., bring the fat column on to the scale if not already on, and read the fat column from the lowest point of the (upper) meniscus to the interface of fat and acid. The lower end of the fat column is brought *down* to the next main graduation. Replace in water bath for a further 3 min. and take another check reading.

Likely causes of faults. *Fluffy layer at bottom of fat column.* (*a*) Repeat the test and see that the rubber bung is satisfactory. (*b*) Not centrifuged long enough or amyl alcohol not added. *See* above. (B.S. 696, 1936.)

Babcock and Gerber Tests Compared. The biggest objection to the Babcock test is that three centrifugings are required. Similarly the greatest drawback of the Gerber test is the necessity for rubber bungs. Carrying out many Gerber tests is rather hard on the fingers, and for this reason a lock stopper consisting of a soft rubber " hollow bung " containing a bead has been brought out.

On most other points the Gerber has the advantage as it is quicker, requires less manipulation, can be performed with a hand centrifuge and uses less material. Either method may be used for routine control purposes but for accurate work a gravimetric method should always be employed.

Refs.: Milk testing; Richmond.

FAT IN MILK PRODUCTS, DETERMINATION OF. The Gerber Method. It is recommended that the British Standard Specification No. 696, Parts I and II, for Gerber Apparatus for Testing Fat in Milk and Milk Products should be used.[1]

Skim milk. Using a skim-milk butyrometer, the procedure is as described for whole milk. For low fat contents the following corrections must be made: for a butyrometer reading of less than 0·10 per cent., add 0·05 per cent.; for readings of 0·10 to 0·25 per cent., add 0·02 per cent.; for readings above 0·25 per cent., no correction is necessary.

Cream (A). Five g. of cream are weighed into the special cream (5g.) butyrometer and 6 ml. of warm water at 30° to 40° C. added, followed by the same quantities of acid and alcohol as for milk. The procedure is then as for milk, and the fat column is read to the bottom of the meniscus. With homogenised and sterilised creams it is imperative to centrifuge again after the first reading and read again. The separation between the fat and acid layers must be distinct; this applies to all homogenised products.

Cream (B). Using the standard (whole milk) butyrometer, *one* g. of cream is weighed into it, followed by 10 ml. of distilled water at 30° to 40° C., the acid and alcohol as for milk. The procedure is then the same as described for milk. The reading of the fat scale is taken to the bottom of the meniscus. The percentage of fat is read from a Table (given in B.S. 696, II, 1936, of the British Standards Institution), connecting the weight taken, fat reading, and the true fat percentage in the product when approximately 1 g. of cream, cheese, or dried milk is taken. (This method (B) covers the determination of fat in the milk products named.)

Cheese. The sample of cheese is shredded finely. Three g. are weighed into a special (3-g. cheese) butyrometer containing 10 ml. of acid and 3 ml. of water above the acid to act as a cushion. One ml. of amyl alcohol and 6·5 ml. of water are then added. The procedure then is as described for milk, the fat column being read to the bottom of the meniscus. In the case of cheese containing over 40 per cent. of fat, 1·5 g. should be taken and the reading multiplied by 2.

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[1] British Standards Specifications may be obtained from British Standards Institution, 2 Park St., London, W. 1.

Dried milk. In addition to the method described under Cream B, 1·69 g. of dried milk may be used in a standard whole-milk butyrometer. The fat reading, read to the bottom of the meniscus, is multiplied by 6·67 to give the true fat percentage.

Refs.: Dolby (1949), *JDR*, **16**, 334; Fort (1949), *IDC*, **5**, 44, 58 (calibration of butyrometers).

FAT, GRAVIMETRIC METHODS. The Gerber and Babcock methods are suitable only for routine control; for accurate and especially for legal determinations a gravimetric method must be used, such as the Röse-Gottlieb, Werner-Schmid, or Adams.

Röse-Gottlieb Method. Ten g. of milk or 2 to 2·5 g. of condensed milk (accurately weighed), 8 g. of water being added to the latter, are transferred to an extraction apparatus and 1 ml. of conc. ammonia solution added. After mixing, 10 ml. of alcohol are added and, after further mixing, 25 ml. ether. The mixture is vigorously shaken for 1 min. and then 25 ml. petroleum ether added and the shaking repeated. After standing for at least 30 min. the clear ethereal layer is separated and the extraction twice repeated. The combined ethereal extracts are evaporated and the fat weighed.

Ref.: Milk testing; Richmond; Soc. Publ. Anal. (1927), *A*, **52**, 402.

Werner-Schmidt Method. This is similar to the Röse-Gottlieb but hydrochloric acid is used to loosen the casein from the fat.

Adams Method. A known amount of milk is absorbed by blotting paper (special fat-free) and, after drying, the paper is extracted by ether in a Soxhlet apparatus in the usual way, and the dried residue weighed.

Ref.: Richmond.

FAT IN MILK, IMPORTANCE OF. The importance of the fat in milk is usually overrated by the public, especially by the housewife. This is understandable, as for cooking, addition to fruit, etc., the fat component is the most valuable from the appearance and " body " point of view. Moreover, it is the only constituent of milk which readily separates and so is obvious to the eye; the housewife tends to judge by the cream line not only the amount of fat in the milk, but also the general richness of the milk. This is, broadly speaking, sound, as milk rich in fat is usually rich in solids-not-fat (protein, etc.), but the cream line is not always a reliable method of estimating fat. Jersey and Guernsey milks, with their yellow fat and large fat globules, always give a marked cream line in a short time, whereas Ayrshire milk, which is somewhat richer than Shorthorn milk, suffers relatively in a cream-line comparison because of its lack of pigment and small fat globules, which require much longer to rise. Cream line has been, perhaps, the most important selling point in milk; some hold that a good cream line counts more than a good keeping quality. This aspect has had a close association with the introduction of glass bottles.

The nutritive value of fat is also frequently wrongly assessed. For example, the consumption of butter, which contains only the fat and the vitamins A and D in the milk, is sometimes given as the milk equivalent, which gives a grossly false picture. To make a reasonably complete food, butter or cream would have to be reinforced with protein, calcium, phosphorus, and vitamins B_1, B_2, and C. On the other hand, skim milk, which is commonly regarded as milk " with most of the goodness taken out," is still very good food and, reinforced with vitamins A and D, might be regarded as an excellent food. Naturally, skim milk is not as good as whole milk, especially in energy value, but of the two parts of the milk there can be no doubt that the skim milk is the more valuable. *See* Nutritive value.

FAT GLOBULES. The fat in milk is present in the form of globules varying in diameter from 0·1 to 10μ or 0·0001 to 0·01 mm., average 3μ. Usually there are from 2 to 4 × 10^9 globules per ml. The volume of fat in 1 ml. is about 0·04 ml. or 4 per cent. and the surface has a total value of about 80 sq. cm.

Proteins lower the surface tension of water and in milk are adsorbed on the fat globules, thus acting as protective colloids and preventing agglutination. The exact nature of this adsorbed layer is not known but it appears to contain casein, albumin, globulin and calcium phosphate. Phospholipoids and mucins may also be present. In freshly drawn milk this "skin" is mobile but later becomes static or solid as the proteins become denatured. It is about 0·0000005 cm. thick and constitutes nearly 2 per cent. of the protein in milk.

The sp. gr. of milk fat is about 0·9 and, in the absence of other factors, the rise of the globules is described by Stokes' law.

$$V = \frac{r^2\,2(d_1 - d_2)g}{9\eta}$$

where V = rate of movement of fat globules; r = radius of globule; d_1 = density of skim milk; d_2 = density of fat globule; η = viscosity of skim milk; g = gravity. Since d_1, d_2, η and g are practically constant, we can write $V = k\,.\,r^2$ or the rate of rise of the globules or formation of the cream layer is proportional to the square of the radius of the globule.

Broadly speaking, the size of the globules varies with the fat of the milk of different breeds, *e.g.* Jersey and Guernsey > Shorthorn > Friesian. The globules of Ayrshire milk are an interesting exception, being roughly the size of those in Friesian milk, although the fat of Ayrshire milk is higher than that of Shorthorn. It is for this reason that Ayrshire milk is considered good for cheesemaking, the small globules leading to a close binding of the fat and casein. *See* Cheese, p. 168.

As lactation advances the globules become smaller and more numerous. For this reason, and also because of increased alkalinity, cream from late lactation milk churns more slowly than normal cream. *See* Butter, p. 131.

It is claimed that feeding of grass, silage and high-oil concentrates tend to produce larger fat globules. *See* Cream line.

Refs.: Adam; Clayton; Davies; Richmond; Rogers; Hansson (1949), *IDC*, **2**, 27; King (1951), *DI*, **16**, 727.

FAT, MILK HIGH IN. Jersey and Guernsey milk is appreciably higher in fat than the milk of Shorthorn and Friesian cows which constitute the bulk of English herds. Such milk can command a higher price (*see* Channel Islands milk), is very attractive to the eye on account of its deep colour and good cream line (p. 167) and for this last reason has associated with it certain problems in relation to the cleaning of utensils, taints, and keeping quality. *See* Breeding; Fallacies; Legal aspects; Quality payment.

FAT, SURFACE ACTIVITY OF. *See* Surface tension.

FATIGUE IN METALS. Metals submitted to repeated alternating stresses fail at a stress well below the normal critical value for static tests. This phenomenon is called "fatigue".

FATTY ACIDS. The general name given to the saturated straight-chain aliphatic series of mono-carboxylic acids of the general formula, $C_nH_{2n+1}\,.\,COOH$. Their common properties are given in Table Fa I.

The more common unsaturated fatty acids are given in Table Fa II.

See Butter; Cheese, p. 168; Constituents; Flavours.

Refs.: Williams, K. A.; Richmond; Rogers; Markley (1947), *Fatty Acids*, N.Y.; Ralston (1948,) *Fatty Acids and their Derivatives;* Bloor (1943), *Biochemistry of the Fatty Acids*, New York; Hilditch; Tucker and Bird (1951), *JDS*, **34**, 1170 (determination); Hiscox *et al.* (1941), *JDR*, **12**, 155; (1938), **9**, 227 and 215 (extraction and estimation of volatile acids in cheese).

TABLE Fa I

Properties of Fatty Acids

Name	*Formula*	*B P C*	*M P C*	*Odour*	*Solubility in water*	*Volatility in steam*	*Occurring in*
Formic	H COOH	100 7	8 4	V pungent	Miscible	+	Some fermentations
Acetic	CH_3 COOH	118 1	16 6	Vinegary	Miscible	+	Acetic acid fermentation
Propionic	C.H COOH	141 1	22	Vinegary	Miscible	+	Propionic acid fermentation
Butyric	C_3H_7 COOH	163 5	− 7 9	Sweaty [1]	5 6	+	B F and butyric acid fermentation
Valeric	C_4H_9 COOH	187	59	Sweaty [1]	3 7	+	Some fermentations
Caproic	C_5H_{11} COOH		− 2	Peppery	0 4	+	B F
Caprylic	$C\ H_{15}$ COOH		16	Peppery	0 25	+	B F
Capric	C_9H_{19} COOH		31 5	Peppery	V slight	+	B F
Lauric	$C_{11}H_{23}$ COOH		44	—	*i*	+	
Myristic	$C_{13}H_{2}$ COOH		58	—	*i*	+	B F
Palmitic	$C_{15}H_{31}$ COOH		64	—	*i*	—	B F.
Stearic	$C_1\ H_{35}$ COOH		69 4	—	*i*	—	B F

i = insoluble B F — butterfat

[1] The purified acids do not possess these characteristic odours *See* Cheese p 168

TABLE Fa II

PROPERTIES OF UNSATURATED FATTY ACIDS

Name	Formula	M P C	Other names	Occurring in
Oleic	C_8H_{17} CH CH C_7H_{14} COOH	13 and 16 C		Almost all natural fats
Decenoic	CH =CH C_7H_{14} COOH			Milk fat only
Dodecenoic	$C\ H_5$ CH=CH C_7H_{14} COOH			Milk fat
Tetradecenoic	C_4H_9 CH=CH C_7H_{14} COOH		Myristoleic	Animal storage fats
Hexadecenoic	C_6H_{13} CH=CH C_7H_{14} COOH		Palmitoleic, or zoomaric	Almost all natural fats
^{6}Octadecenoic	$C_{11}H_{\ 3}$ CH=CH C_4H_8 COOH	30	Petrolesinic	Seed fats
^{11}Octadecenoic	C_6H_{13} CH CH C_9H_{18} COOH	39	Vaccinic	Milk and animal fats
Ricinoleic	C_6H_{13} CH(OH) CH CH CH C_7H_{14} COOH	5		Castor seed oil
Linoleic	C_5H_{11} CH CH CH CH CH C_7H_{14} COOH	5		Almost all natural fats
Linolenic	$C\ H_5$ CH CH CH CH CH CH CH CH $C\ H_4$ COOH	11		Seed oils

FAULTS. This term in dairying usually refers to defects in manufactured products, which may be of bacteriological or chemical origin, or due to bad making methods, packaging, etc. *See* Butter; Cheese, p. 168; Clean milk production; Coliforms; Condensed and evaporated milks; Flavours; Ice cream; Milk powder; Packaging; Stability, microbiological; and specific faults such as Fishiness, etc.

Refs.: McKenzie (1948), *JSDT*, **1**, 129.

FEATHERING OF CREAM. A term applied to the flocculation of fat, etc., on the surface of tea or coffee, particularly with homogenised milk. The most important factors appear to be acidity and pressure of homogenisation (Webb and Holm (1928), *JDS*, **11**, 243; Whittaker (1931), *JDS*, **14**, 177).

Other factors appear to be the type and strength of coffee, salt balance, and rennin production by bacteria. *See* Sweet curdling.

" FEEDER " DEPOT. A depot or dairy which collects milk for sending on to other depots.

Ref.: Williams.

FEEDING OF DAIRY CATTLE. Foodstuffs. Dairy cattle are ruminants and therefore are capable of digesting bulky fibrous foods such as hay and straw. In this respect they are unlike the non-ruminants such as pigs and poultry. These animals require a more concentrated diet and consequently compete more directly with the human population in their demands for foodstuffs. The farm crop which supplies the chief food for cattle in Great Britain is grass which is grazed in summer and conserved for winter use in the form of hay, artificially dried grass, or silage. Other cattle foods include straw, mangolds, turnips, kale, cabbage, cereals, and various by-products from the manufacture of human foods such as oil seed residues after extraction of the oil and sugar-beet pulp which is the residue after the extraction of the sugar.

Numerous methods are used to express the nutritive value of these cattle foods, but all methods indicate (*a*) the energy value of the food, and (*b*) the protein value. Energy values are usually expressed by one of the following methods: (*a*) *Total digestible nutrients* (T.D.N.) which expresses the heat or energy value of the food in terms of digestible starch. This system is widely used in the U.S.A. (*b*) *Net energy values* which have been estimated by laborious experiments, chiefly with mature steers. The system aims to show that part of the energy value of a food which is of direct use to the animal. The values are expressed in " therms ". (*c*) *Starch equivalent* is estimated in a similar manner to net energy, but the values are expressed in pounds instead of " therms ". The " starch equivalent " method is widely used in Great Britain. (*d*) *Scandinavian " fodder units " system* reduces the nutritive value of each foodstuff to the amount needed to equal 1 lb. of barley:

Assessment of the protein value of foodstuffs is complicated by the fact that part of the nitrogen of a foodstuff may be in the form of true protein and part as amide substances. The expression " digestible crude protein " includes both forms of nitrogen, but " digestible pure protein " does not include amide substances. In Great Britain the amide substances are believed to possess about half as much nutritive value as pure protein and consequently the protein value of a food is expressed by the term " protein equivalent " which is the digestible pure protein plus one half the amides. Tables of composition and nutritive values sometimes show only " digestible crude protein " and " digestible pure protein ". Under these circumstances the " protein equivalent " can be calculated by averaging the two values shown in the tables.

The chemical composition and nutritive value of most of the cattle foods are published in numerous tables so that reasonably accurate estimates may be made of any foods which are available. Table Fe I shows average values of a few cattle foods.

TABLE Fe I

COMPOSITION AND NUTRITIVE VALUE OF SOME CATTLE FOODS

Foodstuff	*Authority*	*Average composition per cent. as shown by analysis*						*Nutritive value %*					*Special feature of foodstuff*
		Dry matter	*Protein*	*Oil*	*Soluble carbohydrate*	*Crude fibre*	*Ash*	*Digestible protein*	*Digestible crude protein*	*Digestible pure protein*	*Total digestible nutrients*	*Starch equivalent*	
Oat straw	(*a*)	86·0	2·9	1·9	42·4	33·9	4·9	—	1·0	0·8	—	20·0	High fibre and low nutritive value
	(*b*)	89·7	4·1	2·2	41·0	36·1	6·3	0·7	—	—	44·7	—	
Lucerne hay	(*a*)	83·5	14·2	2·6	29·2	29·5	8·0	—	9·7	6·2	—	27·0	High fibre content
	(*b*)	90·5	14·3	1·8	36·5	29·7	8·2	10·3	—	—	50·3	—	
Mangolds	(*a*)	10·7	1·0	0·1	8·2	0·7	0·7	—	0·7	0·1	—	5·5	High water content
	(*b*)	9·2	1·3	0·1	6·0	0·8	1·0	0.9	—	—	7·0	—	
Barley	(*a*)	85·1	10·0	1·5	66·5	4·5	2·6	—	7·6	7·0	—	71·4	High nutritive value
	(*b*)	89·4	12·7	1·9	66·6	5·4	2·8	10·0	—	—	77·7	—	
Maize	(*a*)	87·0	9·9	4·4	69·2	2·2	1·3	—	7·9	7·4	—	77·6	High nutritive value
	(*b*)	87·0	8·8	4·0	70·9	2·1	1·2	6·8	—	—	82·0	—	
Decorticated cotton seed meal	(*a*)	91·3	43·6	8·0	25·8	7·7	6·2	—	37·6	36·0	—	70·1	High protein content
	(*b*)	92·5	42·7	6·4	27·0	10·6	5·8	34·2	—	—	72·6	—	

(*a*) Extract from British Ministry of Agriculture *Bulletin* 48 (1952).
(*b*) Extract from Morrison, *Feeds and Feeding* (1949), 21st Edit. U.S.A.

Feeding Standards. When a system has been adopted for stating the nutritive value of the various cattle foods, *e.g.* the "starch equivalent" and "protein equivalent", it is then necessary to use the same system to state the standard or optimal requirements of all classes of cattle. The food requirements of cattle are usually classified under the two headings "maintenance" and "production". Maintenance includes the food necessary to maintain the normal bodily processes; production includes the requirements for growth in young animals and for milk or fat production in adults.

The feeding standards for dairy cows published in Ministry of Agriculture *Bulletin* 42 (1938) and widely used in Great Britain are shown in Tables Fe II and III.

TABLE Fe II

AVERAGE LIVE WEIGHTS AND MAINTENANCE REQUIREMENTS PER HEAD, PER DAY, OF COWS OF THE DAIRY BREEDS

Breed	*Average live weight*	*Maintenance requirements*	
		Starch equivalent	*Protein equivalent*
	lb	lb	lb.
South Devon . .	1450	7·6	0·86
Lincoln Red Shorthorn Longhorn	1300	7·1	0·77
Dairy Shorthorn . British Friesian .	1250	6·9	0·74
Blue Albion . Welsh Black . Devon	1150	6·6	0·68
Red Poll	1100	6·4	0·65
Ayrshire .	1000	6·0	0·60
Guernsey .	950	5·8	0·57
Kerry .	850	5·3	0·51
Jersey .	800	5·1	0·48
Dexter	650	4·4	0·39

TABLE Fe III

PRODUCTION STANDARDS (per 10 lb.) IN RESPECT OF MILK OF VARYING QUALITIES

Fat content of milk (%)	*Starch equivalent*	*Protein equivalent*
	lb.	lb.
3·7 to 3·8	2·50	0·50
3·9 to 4·0	2·60	0·52
4·2 to 4·3	2·75	0·55
4·45 to 4·55	2·87	0·57
4·7 to 4·8	3·00	0·60
5·2 to 5·3	3·25	0·65

Table Fe IV taken from *Recommended Nutrient Allowances for Dairy Cattle* published by the National Research Council, U S A (1945) shows feeding standards for growing cattle and for milking cows In this table

TABLE Fe IV

RECOMMENDED NUTRIENT ALLOWANCES FOR DAIRY CATTLE

Weight of animal	*Expected gain*		*Daily allowance per animal*					
	Jersey	*Holstein*	*Digestible protein*	*Total digestible nutrients*	*Calcium*	*Phosphorus*	*Carotene*	*Vitamin D*
lb	lb	lb	lb	lb		g	mg	International units
Growth								
50	0 5	—	0 30	1 0	4	3	From colostrum	150
100	1 0	0 8	0 45	2 0	8	6	6	300
150	1 3	1 4	0 60	3 0	12	8	10	450
200	1 4	1 6	0 70	4 0	13	9	12	600
400	1 2	1 8	0 80	6 5	14	11	25	1200
600	0 8	1 4	0 85	8 5	15	12	35	Exact requirements uncertain
800	1 1	1 2	0 90	10 0	15	12	45	
1000	—	1 3	0 95	11 0	14	12	60	
1200	—	1 2	1 00	12 0	12	12	70	
Maintenance								
700			0 45	6 0	7	7	40	
1000			0 60	8 0	10	10	60	
1200			0 70	9 5	12	12	70	
1400			0 80	11 0	14	14	80	
Pregnancy (per 1000 lb) (Last 6 to 12 weeks)			1 2	14 0	22	17	90	
Lactation (per lb milk)								
3 0 per cent fat			0 040	0 28	1	0 7	Intake affects quantity yielded in the milk	
4 0 per cent fat			0 045	0 32	1	0 7		
5 0 per cent fat			0 050	0 37	1	0 7		
6 0 per cent fat			0 055	0 42	1	0 7		

the energy value of the ration is expressed as "total digestible nutrients" and the protein value as "digestible protein" When using feeding standards in which the nutritive values are expressed in this way, it is necessary, of course, to use similar units for the values of the foods in the ration (*see* Table Fe I)

The amount of dry matter in a ration is a useful guide to indicate whether the ration will satisfy but not exceed the appetite of an animal An average sized cow needs about 16 lb dry matter per day and the amount should not exceed about 33 lb. even for a high yielding cow From the foregoing feeding standards it will be seen that the nutrient requirements of a Shorthorn cow yielding 30 lb. milk per day are (*see* Tables Fe II and Fe III):

	Starch equivalent	*Protein equivalent*
For maintenance . .	6·9	0·74
For production of 30 lb. milk	7·5	1·50
Total . .	14·4	2·24

A typical winter ration supplying these requirements would be: good meadow hay, 14 lb.; mangolds, 25 lb.; a concentrate mixture of equal parts oats, barley, maize, and decorticated cotton seed meal, 10½ lb.

These feeding standards represent a plane of nutrition which, under average conditions, is most suitable and economical for dairy cows. If protein is fed in excess of the standards there is no marked benefit nor harm, but if less protein is fed there may be a loss in live weight and in milk yield. Marked protein deficiency also causes a slight decrease in the solids-not-fat percentage of the milk.

The effect of varying the amount of energy supplied by the rations is reflected in live weight, in milk yield, and in cases of marked deficiency the solids-not-fat percentage of the milk is reduced. The average effects of varying intake on milk yield is shown in Table Fe V.

TABLE Fe V

Level of feeding expressed as percentage of feeding standards	*Increase in lb. of milk to be expected from each additional lb. of concentrated foods given*
90	1·4
100	1·0
110	0·8
120	0·6
130	0·5

In summer-time cows obtain their food by grazing. Supplementary foods are sometimes necessary when grass is in short supply or when cows are producing very heavy milk yields.

Calf Feeding. Calves which are allowed to suckle their dams, thrive and grow more rapidly than those reared by any other method. In order to economise, however, dairy calves are usually removed from their dams and fed from a pail. When this is done the first food of the newborn calf should be the first milk (colostrum) yielded by the dam. This colostrum when assimilated by the calf, gives it protection against certain calf diseases and also provides essential dietary factors.

A satisfactory and widely used method of calf feeding is to allow the calf to suckle its dam for 4 days, then remove it and feed about 10 lb. whole milk per day for 4 to 6 weeks. The diet is then gradually changed to water, dry concentrated foods, and hay.

The rate of growth of the newborn calf is extremely rapid and the food requirements can be met only by concentrated and easily digested foods. Gradually the growth rate declines and the digestive organs of the young animal become adapted to deal with more bulky foods. Animals of one year and older are able to thrive on rations with ingredients similar to those mentioned for cows.

The vitamin requirements of young dairy cattle are shown in Table Fe IV. A point of some importance is that growing cattle need vitamins A and D. There is some evidence that calves also need certain components of the vitamin B complex during the first few weeks of life before the rumen has started to function.

As soon as the calf becomes a ruminant, however, it synthesises adequate amounts of vitamin B for its own needs. *See* Agriculture; Composition of milk, factors affecting; Digestion; Management of dairy cattle; Nutritive value.

FERMENT. The old name for an enzyme (p. 448).

FERMENTATION. This term means strictly the decomposition of carbohydrates (sugars) by micro-organisms in the absence of air, *i.e.* respiration and oxidation (in the ordinary sense) do not occur. In dairying, by far the most important fermentation is the lactic acid fermentation or ordinary souring of milk. This is because in milk at ordinary temperatures the lactic acid bacteria (p. 576) are able to grow faster than other types. Other fermentations take place to a less extent, especially in cheese and butter and are largely responsible for flavour production (*see* Acetic acid; Butyric acid). Some fermented milks undergo an associated alcoholic fermentation, as in Kefir (p. 566).

Refs.: Burke; Prescott and Dunn; Stephenson.

FIBRE. *See* Composition of milk, factors affecting; Feeding.

FIBRIN. The insoluble thread-like protein in a clot of blood.

FILMS. Substances which have the power to attach themselves to surfaces can cause films to be formed. Milk is notorious in this respect on account of the proteins, particularly the water-soluble albumin and globulin, fat and certain salts, especially the calcium phosphate. Milk which is allowed to dry on utensils forms a film which may be difficult to remove without the use of hot detergent solutions, hence the importance of rinsing immediately after use (*see* Cleaning). When milk is heated, some of the protein and calcium salts may be precipitated and form a skin or film on the surface or on utensils and plant. A " build-up " of this film results in the formation of milk-stone (p. 739) which is not removed by alkaline detergents (p. 367) and requires treatment by acid descaling solutions (p. 366) or hexametaphosphate.

The film or adsorbed layer of protein is responsible for the stability of fat globules and the foaming of milk, especially at low temperatures. *See* Detergents; Surface tension.

Refs.: Clayton; Adam.

FILTERABLE FORMS OF BACTERIA.

Refs.: Kleineberger-Nobel (1951), *BR*, 15, 77.

FILTERING OF MILK. Milk is usually filtered (i) at the farm; (ii) on tipping at the depot; (iii) during pasteurisation.

The use of cloth filters is practically universal, and these remove gross dirt, hairs, etc., but not bacteria or body cells. (*Cf.* Fig. Ce 6.) Attempts have been made to remove bacteria by special filters or by impregnating cloth with certain substances but without success so far.

Filter cloths must be thoroughly cleaned and sterilised at frequent intervals, otherwise a dirty filter can easily do more harm than good. Visible dirt does not affect keeping quality and filtering does not usually increase the keeping quality of milk. *See* Clean milk production; Pasteurisation; Testing of milk supplies.

" FINISHED " MILK. Milk which has been pasteurised and is awaiting bottling.

FINLAND.

Refs.: Kaukonen (1949), *IDC*, 4, 545; Sysiharju, 798.

FISHINESS IN DAIRY PRODUCTS. (1) **Chemical.** Owing to its physical properties, the fatty material of dairy products is much more resistant to breakdown than the protein and carbohydrate constituents, but, under certain conditions, even the fatty material can undergo deterioration yielding various taints and flavours in the product.

The fat in milk products. The fat of dairy products is more reactive to certain agents owing to (*a*) the very fine state of division of the fat which entails the exposure of a very large area per unit weight of fat, (*b*) the presence of a hydrophilic colloid, such as lecithin, which acts as a sympathetic agent between the aqueous and fat phases. In this connection, lactic acid and free fatty acids are of significance, as well as the inorganic salt content of the product in which lecithin is slightly soluble. In butter, where the emulsion has been converted from the oil-in-water to the water-in-oil type, the condition of high area exposure is still maintained. Lecithin is a peculiar fat-like substance, which is more reactive than fat proper and, therefore, where conditions are such that fat will tend to deteriorate, it is the lecithin which will first break down. In lecithin, one of the groups attached to the glyceryl radical is a phosphoric acid-choline complex and, under conditions of oxidation this complex is attacked and the choline is oxidised to give trimethylamine :

$$-CH_2 . O . PO(OH)_2—C_2H_4 . N(CH_3)_3OH \rightarrow$$
$$—CH_2 . O . PO(OH)_3 + N(CH_3)_3 + 2CO_2 + 2H_2O.$$

The breakdown of choline is similar to the breakdown of amino acids to yield free ammonia by Fenton's reagent (hydrogen peroxide in the presence of ferrous salts). The presence of free trimethylamine formed in this manner confers on the product a pronounced fishy taste and smell.

The breakdown of the lecithin thus occurs first, but is followed immediately by the oxidation of the proper fat which gives rise to the form of rancidity known as " tallowiness ". Under very strongly catalysed action to oxidation the " fishy " taint is hardly observable, being submerged by the quick development of the tallowy taint, but with slowly catalysed oxidation the fishy period is longer and more easily detected.

The occurrence of " fishiness " in stored butters is thus partly ascribed to the presence of metallic contamination of the butter by small traces of metals dissolved off the factory equipment during the collecting and processing of the cream and its churning into butter. The use of properly tinned or otherwise non-corrosive equipment would minimise the appearance of this fault in stored butters.

Refs. : Davies ; Rogers ; Davies, H.M. (1940), *Investigation on Herring Meal with Special Reference to its Use as a Food for Pigs and to the Causes of Fishiness*, Univ. Reading, Ph.D. thesis ; Lea (1938), *Rancidity in Edible Fats*, H.M.S.O.

(2) **Bacterial.** Fishiness due to bacterial activity is rare and is due to Gram-negative rods of various types.

Refs. : McKenzie (1946), *SAB*, p. 89 ; Cusick (1920), *JDS*, **3**, 194.

FLASH PASTEURISATION. This term covers all short-time heat treatment methods which are not scientifically controlled. It was formerly used extensively, especially on the Continent, and for milk destined for manufacturing purposes, but has now been almost entirely superseded by the accurately controlled H.T.-S.T. process (p. 790).

Refs. : Cuttell ; Hill.

" **FLASHING.**" A loose term indicating the heating of milk to a temperature of 160° to 180° F. for an undefined time. *See* Flash pasteurisation.

" **FLAT SOUR** ". A canned product (*e.g.* evaporated milk) which sours without the production of gas. *See* Condensed and evaporated milk; Packaging.

FLAVOURS IN MILK. The question of flavour in milk, as in any food product, is one of outstanding importance. There is no market for any food, no matter how valuable from the nutritional point of view, unless the flavour is agreeable or is at least devoid of any unpleasant element. Milk is a complex and highly unstable liquid food, subject to many spontaneous changes, not only at room temperature, but also at refrigeration temperatures.

From the scientific point of view we may classify the flavours occurring in milk as normal and abnormal, the latter being further classified as physiological (*e.g.* feed and weed taints), enzymic (*e.g.* rancid), chemical (*e.g.* oxidised and cooked flavours), bacteriological (*e.g.* souring and bitterness) and mechanical or accidental (*e.g.* paraffin and soap flavours). This classification is summarised in Table F I.

Broadly speaking, it may be said that flavours under A decrease on standing; those under B, C, and D increase; and the accidentally induced flavours under E remain unaltered.

TABLE F I

CLASSIFICATION OF FLAVOURS IN MILK

NORMAL	*Examples and causes*
" Cowy " (slight)	Lower fatty acids, acetone bodies, etc.
ABNORMAL	
A. *Physiological*	
(1) Excessive " cowiness "	Incomplete fat metabolism
(2) Feed flavours	Volatile principles of feeding stuffs. Silage, turnip, kale, and beet taints
(3) Weed taints	Volatile principles of weeds. Camomile, garlic, etc.
B. *Enzymic*	
(1) Rancid	Hydrolysis of milk fat by lipase
C. *Chemical*	
(1) Oxidised flavour	Mild oxidation of lipid (?)
(*a*) Copper catalysed—correlated with high O/R potential	
(*b*) Spontaneous—(?) independent of O/R potential	
(Largely controlled by B.O.D. and reducing substances in the milk)	
(2) Activated flavour	Irradiation of milk resulting in change in albumin (?)
(3) Cooked flavour	Formation of sulphydryl compounds by heat (Appears when milk is heated to 80° C.)
D. *Bacterial* (*Growth Products of Micro-organisms*)	
(1) Souring	*Str. lactis*, etc.
(2) Caramel and malty	Atypical strains of *Str. lactis*
(3) " Unclean " odours	Coliforms, cocci, Gram-negative rods
(4) Amyl alcohol	*Micrococcus sp.*
(5) Vinegary	Various
(6) Fruity	Yeasts (mainly)
(7) Carbolic	Spore-forming bacillus in sterilised milk
(8) Bitter	Aerobic spore formers, etc.
All these are due to unclean methods of production, dirty utensils, and holding milk above 65° F.	
E. *Mechanical*	
(1) Paraffin	
(2) Soap	
(3) Chlorine disinfectants	
(4) Paint, etc. (by absorption of volatile constituents)	

Normal Milk Flavour. Freshly drawn milk from a healthy udder has a characteristic flavour, best described as " cowy ". It is impossible to define this, but it is most probably due to a complex mixture of lower fatty acids and their condensation or oxidation products, " acetone bodies " (acetone, acetoacetic acid, and hydroxybutyric acid), carbon dioxide and other volatile products occurring normally in small quantities in tissue fluids. When accentuated it is objectionable, and one of the reasons given for aerating milk, *e.g.* over the cooler, is to liberate these volatile compounds and so reduce " cowiness " to a negligible proportion. It has been stated that when " cowiness " is excessive it can be reduced by increasing the proportion of carbohydrate in the ration. This is, of course, based on the assumption that " cowiness " is due largely to the intermediate products of metabolism of fats (acetone bodies), and that " fat burns in the flame of carbohydrate ".

Milk from an udder infected with mastitis may be already tainted as the result of bacterial growth inside the udder. Hence the necessity of stressing the importance of the " healthy udder " when speaking of " normal milk ".

Physiological Taints. ***Feed flavours.*** Perhaps the commonest form is that due to feeds of various sorts. The following tables are very instructive, as showing the preponderance of feed flavours in milks having off-flavours in America (Tables F II and III). (Weaver)

TABLE F II

Defect	*No of times noted*	*% of all observations*
Feed	2305	36
" Cowy "	1347	22
Rancid	910	14
Stale	872	14
Salt	568	9
Flat	457	7
Sweet	164	3
Bitter	135	2

Samples held 15 hr at 40 F

TABLE F III

COMPARATIVE INCIDENCE IN EACH SEASON

(*Per cent of Total Observations Each Season*)

Defect	*Spring*	*Summer*	*Autumn*	*Winter*
Feed	42	29	28	43
" Cowy "	21	21	27	19
Rancid	6	9	22	17
Stale	11	28	11	9
Salt	6	9	10	10
Bitter	0	1	5	2
Nil	13	5	6	7

Defect	*After 24 hr*				*After 72 hr*			
	Raw	*Holder pasteurised*		*Flash past*	*Raw*	*Holder pasteurised*		*Flash past*
		Unaerated	*Aerated*			*Unaerated*	*Aerated*	
Feed	30	20	17	20	13	13	10	16
Heated	2	34	29	14	4	30	26	12
Oxidised	2	3	94	2	4	18	19	14
Nil	43	28	27	47	26	21	22	33

Figures give percentage of cases with a particular defect after various treatment and storage at 40 F for 24 and 72 hr

Feed flavours are thus commonest in winter and spring, *i.e.* when artificial feeding stuffs are fed and grass is not available. Such flavours can usually be attributed to definite feeds, *e.g.* silage, turnip, kale, beet, etc.

They are definitely due to absorption of the volatile constituents of the feed via the bloodstream and not to absorption of " barn odours ".

Pasteurisation reduces the percentage of milks judged to possess feed flavours, but it must be remembered that this process may increase the proportion of " heated " or " cooked " flavours.

Weed Taints. These naturally occur at definite times of the year, usually in spring and summer.

Weed taints are naturally more frequent when pasture is scarce. Certain cows may, however, show a predilection for certain weeds even when pasture is abundant (Table F IV). (Miller.)

TABLE F IV

WEED TAINTS

Plant	*Flavour produced*
Buttercups (*R. acris*)	Bitter
Buttercups (*R. repens*)	Unpleasant
Butterwort (*Pinguicula vulgaris*)	Disagreeable
Camomile (*Anthemis arvenis*)	Disagreeable
Stinking camomile (*A. cotula*)	Disagreeable
Wild camomile (*Matricaria chamomilla*)	Disagreeable
Cowbane (*Cicuta virosa*)	Acrid
Fools' parsley (*Æthusa cynapium*)	Unusual odour
Garlic (*Allium sp.*)	As of onions
Henbane	Unpleasant
Hemlock	Unpleasant
Green hellebore (*Helleboris viridis*)	Bitter
Stinking hellebore (*H. foetidus*)	Bitter
Black hellebore (*H. niger*)	Bitter
Ivy (*Hedera helix*)	Bitter
Lesser wartcress (*Senebiera didyma*)	Unusual
Hogwood (*Polygonum aviculare*)	Bitter
Lesser sium (*Sium angustifolium*)	Disagreeable
Mint (*Mentha sp.*)	Minty - inhibitory to rennet action
Acorns	(Cheese develop sharp acid flavour in ripening)
Pennycress (*Thlaspi arvense*)	Disagreeable
Rhododendron	Bitter
Runch (*Raphanus raphanistrum*)	Bitter
Tansy (*Tanacetum vulgare*)	Bitter
Turnips	Turnip taint
Water parsnip (*Sium latifolium*)	Objectionable
Wood anemone	Disagreeable
Wormwood (*Artemisia absinthium*)	Disagreeable
Yarrow (*Achillea millefolium*)	Bitter

Enzymically Produced Taints. Under this heading may be considered taints produced as a result of the activity of inherent enzymes in the milk. Although strictly speaking physiological, it is convenient to separate these from weed and feed flavours, as there is an important practical difference between them. Whereas feed and weed flavours are strongest when the milk is freshly drawn from the cow and tend to pass off on standing, especially if the milk is aerated, enzymically produced taints may be undetectable on first milking, but become increasingly noticeable on standing. In this respect they resemble chemical and bacteriological taints. The outstanding taint in this category is that of rancidity. " Cowiness " is often a forerunner of this defect, which is a serious one commercially, as there is no way of removing the taint once initiated. Rancidity and bitterness sometimes go together, and it may be recalled that tributyrin is exceptionally bitter. A tendency to give milk liable to rancidity may be inherited, and there is a suggestion that high fat milk is more likely to develop rancidity than low-testing milk. Rancidity is a more potent cause of deterioration of flavour when cows are in advanced lactation than when in full milk, or, in other words, the lipase content may be assumed to increase more than usual in the milk of cows liable to give this type of milk. Stale and oxidised flavours do not appear to be dependent on the stage of lactation ; saltiness, however, increases as the sodium chloride rises and the lactose falls with advancing lactation. Rancidity is also seasonal, being at a maximum in autumn and winter.

Chemically Produced Taints. Under this heading are considered chemical changes brought about by such substances as copper, or such conditions as heat or irradiation.

Oxidised Flavour. This characteristic flavour (oiliness, " cardboard " flavour, etc.) is common in America, but only of casual interest in this country at present. This is undoubtedly due to the greater extremes of temperature in America, the milk being naturally cold in winter and refrigerated in the hot summers. The taint is associated with low bacterial counts and low temperatures, *i.e.* it is related to the biological oxygen demand of the milk. Although of secondary importance at present, an increase in refrigeration in the dairy industry and in the household is bound to result in an increase of this defect in this country.

Two types of oxidised flavour are recognised : (1) That due to contamination with copper from worn coolers, etc., and (2) that independent of copper and occurring in certain types of milk.

Golding and Feilman observed in 1905 that copper contamination in milk could lead to a characteristic taint, and Mattick studied the factors controlling the effect of copper, showing that copper raised the O/R potential of milk from + 0·2 v. to about + 0·4 v., at which potential oiliness could develop. He also showed that bacterial growth prevented oiliness by lowering the potential to a point at which the oxidative changes necessary for oiliness could not take place.

Greenbank has investigated the O/R potential as a factor in producing oxidised flavour. He concludes that this taint is the result of oxidation of some minor constituent of milk, as it is favoured by low storage temperatures, copper, diffuse light, and small amounts of hydrogen peroxide. Heating the milk prevents oxidised flavour, presumably because of the production of reducing substances associated with " cooked flavour ", while high concentration of H_2O_2 and aeration inhibit the fault by further oxidation of the partially oxidised product responsible for the flavour. Greenbank represents his theory diagrammatically as follows :

$$\begin{array}{ccccc} & \textit{Mild Oxidation} & & \textit{Stronger Oxidation} & \\ \text{R} & \longrightarrow & \text{R.O.} & \longrightarrow & \text{R.O}_2 \\ \text{(odourless)} & & \text{(oxidised flavour)} & & \text{(no oxidised flavour)} \end{array}$$

Copper is effective as a catalyst, because it raises the E_h but does not cause rapid oxidation. A milk that is well poised, *i.e.* has a high " buffering " effect towards changes in O/R potential, will be resistant to the taint. Greenbank is of the opinion that the fat glycerides are probably not the precursor, but lecithin may be. It is almost certainly a minor constituent.

Enzymes are not responsible, as the taint is best produced at $-17°$ C., and in addition it can develop in milk heated to 185° F. for 5 min., but not if aerated afterwards. Low temperatures are effective because of the retardation of oxidation of intermediate compounds.

Barkworth has emphasised the fact that some milks are so susceptible that they develop oxidised flavour without contamination with copper or exposure to sunlight. In England copper is usually the cause of the trouble and the milk soon acquires a " castor oil " taste. Oiliness, " cardboard ", " tallowy ", and " cappy " are terms all used to describe this same phenomenon.

The problem of oxidised flavour is quite obviously related to the presence of oxidants and reductants in the milk. It is not surprising, therefore, that numerous papers attempting to correlate susceptibility to oxidised flavour with the concentration of carotene, vitamin A, riboflavin (vitamin B_2), ascorbic acid (vitamin C), and other reducing substances have been published in the last few years. Many workers found that feeds high in carotene and vitamin C resulted in milks also high in these vitamins and in which the amount of oxidised flavour was considerably reduced.

Activated Flavour. Brief mention may here be made of a characteristic taint induced by irradiation and direct sunlight. The fault is also described as " flat " in its early stages and " mushroom ", " burnt ", " burnt feather ", and " burnt protein " in its later stages. On the Continent the term " emery " is also used. Weckel and Jackson state that this taint is to be differentiated from oxidised flavour and becomes more noticeable when the milk is heated to 82° C. The taint substance appears to originate from methionine and riboflavin (Patton and Josephson (1953), *S*, **118**, 211; Trout and Weinstein (1953), *IDC*, **3**, 1061 (homogenised milk)).

Cooked Flavour. Milk heated to over 170° F. has a characteristic odour. This is usually attributed to volatile substances containing sulphur and possibly phosphorus and iodine. It is fairly easy to tell over-pasteurised milk, but difficult if a temperature of 145° F. has not been exceeded. Pasteurised milk has, however, a relatively flat taste due, at least in part, to the loss of carbon dioxide. Milk treated by the high-temperature short-time process is less liable to suffer in this way, as both heating and cooling take place under pressure.

With flavours due to heating the milk, as with those induced by other agents, experts have attempted to differentiate degrees of flavour intensity. Thus Gould and Sommer suggest that the term " pasteurised " or " heated " be used for low-temperature effects, while the terms " cooked " or " scorched " be reserved for more drastically treated milk. The latter has a sharply defined critical temperature. They were able to detect sulphydryl compounds in milk heated to 80° C. and observed that the O/R potential was lowered. The appearance of cooked flavour could be correlated with the formation of sulphydryl compounds, and it is suggested that the H_2S is derived from the serum or fat, not the casein. Josephson and Doan have obtained similar results, and conclude that lactalbumin and/or the " fat globule membrane substance " are the sources of H_2S.

Gould and Sommer have further studied the effect of oxidants and reductants on the appearance of oxidised and cooked flavours. When copper was added before heating, the cooked flavour did not appear until a temperature of 183° F. was reached. Milk only heated to temperatures below this developed oxidised flavour. If added after the heat treatment, both flavours could be produced. Gould further observed that the appearance of cooked flavour coincided with the destruction of peroxidase.

Bacterial Flavours. In spite of the tremendous amount of research, education, and propaganda in the cause of clean milk production, bacteria are easily the major cause of taints in milk in this country, and the annual loss must be counted in hundreds of thousands of pounds. The vast quantity which is not quite bad enough to be rejected is a constant source of anxiety to those responsible for the quality of the liquid milk, butter, cheese, and other milk products in this country. Ordinary souring is, of course, the commonest bacterial taint in this as in other countries, and it is most frequent in the hot months of June, July, and August. Its occurrence is also appreciable, however, in mild periods at other times of the year, *e.g.* in November, as farmers have by then usually relaxed the preventive measures, such as cooling, which are practised in summer.

Broadly speaking, all bacterial faults in milk (*e.g.* souring, bitterness, specific odours, colour faults, sweet curdling) are due to allowing large numbers of bacteria to gain access to the milk and/or maintainingthe milk at relatively high temperatures (*e.g.* over 65° F.).

Accidental Flavours. The most frequent of the flavours coming in this category are paraffin, soap, and chlorine disinfectants. These are usually " all or nothing " and the cause is obvious. Occasionally, however, micro-organisms under certain conditions produce substances which might be thought to have been introduced in this way. Instances of this are the carbolic taint in sterilised milk (presumably phenol derived from tyrosine), and the caramel and malt flavours produced by atypical strains of *Str. lactis.* Many bacteria can produce a vinegary taint, and yeasts and a few bacteria can produce the aromas of specific fruits.

The great power that milk possesses for absorbing odours should not be overlooked. This is due to the chemical forces at the surface of the fat globules, the adsorbing power being associated with the creamy part of the milk. (Incidentally, the surface area of the fat in 1 pint of Shorthorn milk is of the order of 100,000 cm.^{2} or 100 sq. ft.) Cakes and other foods containing cream placed in a recently stained or varnished cupboard, for example, may become so impregnated with the volatile constituents in the stain or varnish as to be uneatable. Milk and cream should, therefore, never be allowed to stand in an atmosphere containing odours of any kind. *See* Auto-oxidation; Butter; Cheese, p. 168; Condensed and evaporated milk; Milk powder; Platform tests; Stability

Refs.: Moncrieff; Crocker (1945), *Flavor*, New York; Parker (1922); *Taste, Smell and the Allied Senses*, New York; Lea (1953), *IDC*, **3**, 1037; *CI*, 1303; Aule and Storgårds (1953), *IDC*, **3**, 1076 (oxidised flavour), Shtal'berg and Kretovich (1953), *MP*, **14** (5), 27 (milk powder); Forss (1953), *AJDT*, **8**, 61 (ant flavour); Forster and Sommer (1951), *JDS*, **34**, 992 (oxidised flavour); Weaver (1939), *Okla. Agric. Exp. Sta Tech. Bull.* 6, Golding and Feilman (1905), *JSCI*, **24**, 128; Mattick (1930), *Ph.D. Thesis*, London; Greenbank (1940), *JDS*, **23**, 725; Barkworth (1938), *AP*, **15**, 35; (1938), *DI*, **3**, 367; (1944), *D*, Nov. p. 4, Dec. p. 13; Weckel and Jackson (1936), *FR*, **1**, 419; Gould and Sommer (1939), *Mich. Sta. Coll. Tech. Bull.* 164; Josephson and Doan (1939), *MD*, **29** (2), 35, Gould (1940), *JDS*, **23**, 37.

FLEISCHMANN'S FORMULA. A formula connecting the specific gravity of milk with the specific gravities and contents of fat and the solids-not-fat.

$$D = \frac{100np}{np(100 - T) + nF + p(T - F)}$$

where n = sp. gr. of solids-not-fat; p = sp. gr. of fat; F = fat content; T = total solids content; D = sp. gr. of the milk. Assuming p to be 0·93 and n 1·60 the formula becomes

$$D = \frac{1000}{1000 - 3{\cdot}75(T - 1{\cdot}2F)}$$

which can be modified to

$$T = \frac{G}{4} + \frac{6F}{5} + 0{\cdot}25$$

G = degrees of gravity (p. 366), which approximates to Richmond's formula, now in common use (p. 1034). *See* Lactometer; Solids-not-fat; Total solids.

FLIES. Flies can be a serious cause of infection of animals and of milk. Summer mastitis (p. 660) in cows is attributed to flies acting as carriers of *C. pyogenes*, and the fault known as sweet curdling (p. 1002) has been associated with fly contamination in the dairy and milking shed.

If flies are prevalent in the cow shed or dairy, positive steps should be taken by removing all traces of food, milk residues, etc., and if necessary by the application of the well-known insecticides, bearing in mind the readiness with which milk absorbs odours (p. 477).

The use of blue glass is said to help keep away flies. *See* DDT; Insecticide·

FLOORS. The floor problem is one of the most important in the industry. The ideal floor should be, (i) non-slippery ; (ii) easily washed down and cleaned (good fall) ; (iii) hard wearing ; (iv) even wearing (no depressions) ; (v) reasonably cheap.

Ordinary concrete develops cracks and depressions and the system of iron grids let into concrete is one of the most popular. An alternative is one of grids let into asphalt mounted on concrete. All these methods, however, lead sooner or later to cracks or uneven portions, especially depressions, which accumulate milky residues and so easily become stinking.

Very good results have been obtained with very hard acid and alkali resisting tiles. Suitably set in a bituminous compound on a firm foundation, such tiles can give an almost perfect dairy floor, being very hard wearing. They are, however, expensive and special composition stone material, *e.g.* granolithic, may be adequate for those parts of a dairy where the wear is less.

A good fall, *e.g.* about 1 in 40, is always an advantage, permitting frequent washing down into a gulley where this is practicable and permissible.

For laboratories and offices, rubber or rubber type plastic flooring can be recommended. *See* Dairy farm buildings; Design of dairies; Management of creameries.

Refs.: Harper (1951), *D*, **68**, 417; (1951), *JSDT*, **4**, 184.

FLOW DIVERSION. The system in H.T.-S.T. pasteurisation (p. 790) which diverts the milk back into the raw balance tank if it has not been heated to at least 161° F.

Ref.: Cuttell.

FLOW OF LIQUIDS. There are two types of flow of liquids in a pipe, etc., turbulent and non-turbulent or laminar. The velocity at which the laminar flow changes to turbulent is called the *critical velocity*. This is controlled by the diameter of the pipe (internal), average velocity, density, and viscosity of the liquid. The expression $\frac{Du\rho}{\mu}$ is called the *Reynolds number* and is of fundamental importance in all problems of liquid flow. In a straight circular pipe the flow will be viscous when the Reynolds number is below 2100 and turbulent when over 4000. D = diameter in ft. ; u = velocity in ft./sec. ; ρ = density in lb./ft.^{3} ; μ = viscosity in lb./ft./sec.

In H.T.-S.T. pasteurisation plant great care is taken to obtain turbulent flow in order to ensure uniform temperature conditions and the most rapid heat transfer throughout a mass of liquid.

Refs.: Badger and McCabe ; McClain (1952), *Fluid flow in pipes;* Linford (1949), *Flow measurement and meters.*

FLUID. Any liquid or gas.

FLUIDITY. The property of flowing possessed by gases and liquids. Fluidity and viscosity are inverse characteristics. The unit of fluidity is the *Rhe*. *See* Rheology; Viscosity.

FLUORESCENCE. The emission of a radiation in the visible range of a different wave-length from that falling on a substance. The incident radiation may or may not be visible.

Fluorescence is a characteristic property of some compounds, especially the pigments. The most important fluorescent phenomena in dairying are those of riboflavin (vitamin B_2 factor) in whey and of the fluorescent bacteria sometimes evident in dairy products held at low temperature.

Ref.: Radley and Grant (1954), *Fluorescence Analysis in Ultra-violet Light*, London; Pringsheim (1949), *Fluorescence and Phosphorescence.*

FLOURESCENT BACTERIA. A general term applied to those bacteria which produce a fluorescent pigment. These are included in the genus *Pseudomonas* which consists of Gram-negative non-spore-forming rods attacking protein and fat and also (but less frequently) carbohydrates. They grow well at low temperatures and are common in water, especially ponds, etc. Clean milk which is held at low temperatures, *e.g.* below 50° F. may become rich in such bacteria and exhibit a fluorescent " shimmer " after a few days. *See* Classification.

FLUORINE AND FLUORIDES. Fluorides were at one time used as a preservative in milk and butter but are no longer of any importance in this respect.

FOAMING. A foam is an " emulsion " of a gas (air) in a liquid.

(i) **In Milk.** Foam formation is favoured by substances being adsorbed at surfaces or lowering the surface tension (*see* Adsorption). For the foam to be enduring, the internal viscosity of the particles of the film must be high. Thus, low temperatures favour foaming in milk not only because of the protein changes but also because of the solidification of the fat and lipoids. Milk foams least between 68° and 84° F. (20° and 30° C.) and the tendency to foam increases markedly above 84° F. Surface tension does not account entirely for the ease of foaming.

Foam may also be caused by gas production by micro-organisms, *e.g.* coli (Sarles and Hammer (1933), *JB*, **25**, 461).

(ii) **In Bottle-washing Machines.** This is an erratic phenomenon, but when it occurs the machine must be stopped and cleaned out. Some types of machine tend to produce foaming, and certain detergents and constituents of detergents produce foaming if used above certain concentrations. *See* Bottle washing; Detergents.

Ref.: Brunner (1950), *JDS*, **33**, 741 (antifoaming agents).

" FOBBING." A term used in the trade to describe foaming, especially in relation to foaming of detergent solutions in bottle-washing machines. *See* Bottle washing; Detergents.

FOOD. *See* Economic nutritional values; Feeding dairy cattle; Nutritive values.

FOOD, MILK AS.

Refs.: Bransby, Magee, Bowley and Stanton (1947), *BJN*, **1**, 275; " The Food Needs of the United Kingdom "; Brock and Autret (1952), *Kwashiorkor in Africa*, " F.A.O. Nutritional Studies, No. 8, Rome "; Commonwealth Economic Committee (1952), *Dairy Produce:* " A Summary of figures of production, trade and consumption relating to butter, cheese, condensed milk, milk powder, casein, eggs, egg products, margarine ", London: H.M.S.O.; Corry Mann (1926), *Diets for Boys during School Age*, " M.R.C. Special Report Series No. 105 "; Crawford and Broadley (1938), *The People's Food*, London; Dean (1952), *BMJ.*, **2**, 791, " Treatment of Kwashiorkor with milk and vegetable proteins "; Drumond and Wilbraham (1939), *The Englishman's Food*, London; Food and Agriculture Organisation (1949), " Food Balance Sheets, Washington "; Food and Agriculture Organisation (1950), " Supplement to Food Balance Sheets ", Washington; Hollingsworth (1951), *BJN*, **5**, 392; " Trends in Milk Consumption in Great Britain "; League of Nations (1937), " Final Report of the Mixed Committee of the League of Nations on the Relation of Nutrition to Health, Agriculture and Economic Policy ", Geneva; Ministry of Food (1951), " First Report of the National Food Survey Committee, The Urban Working Class Household Diet, 1940 to 1949 ", London: H.M.S.O.; Ministry of Food (1952), " Bull. Ministry of Food No. 655 ", p. 8, Food Consumption Levels; Ministry of Health (1937), " First Report of the Advisory Committee on Nutrition ", London: H.M.S.O.; Ministry of Labour (1940), *Ministry of Labour Gaz.*, **48**, 300; Murray and Rutherford (1941), *Milk Consumption Habits*, Oxford; " Agricultural Economics Research Institute "; Soulides (1949), " Better Utilisation of Milk, F.A.O. Agricultural Studies, No. 7 ", Washington; Trowell and Davies (1952), *BMJ*, **2**, 796. " Kwashiorkor I, Nutritional Background, History and Distribution "; Trowell, Davies and Dean (1952), *BMJ*, **2**, 798, " Kwashiorkor II, Clinical Picture, Pathology and Diagnosis "; Tsongas (1951), Nutrition Work in Greece, " F.A.O. Nutritional Studies No. 7 ", Rome.

See Infant foods; Mammals; Nutritive values.

FOOD AND DRUGS ACT, 1938-50. This comprehensive act covers most aspects of the law controlling the sale of food. The following sections are of interest to dairymen: 1 to 8: general, definitions, labelling, adulteration, and abstraction; 14, 16, and 37: ice cream; 20 to 26: milk and dairies (most important part); 24: additions to milk; 25: diseases in cows, especially T.B.; 32 to 36: butter, margarine, and cheese; 27 to 29: artificial cream (reconstituted from butter and milk solids); 68 to 71: sampling; 73: inspection of manufacturing premises; 100: definitions of dairy products. This Act is now under revision and a new comprehensive Act is expected. *See* Legal aspects.

Refs.: Bell; Enock; Harvey and Hill; Richmond; Swift; Ashford and Savage (1938), *Food and Drugs Act*, 1938, London.

FOOD POISONING. Outbreaks of food poisoning are nearly all characterised by the sudden appearance of gastro-intestinal symptoms, *e.g.* vomiting and diarrhoea. Of the few exceptions, botulism is the most important. The causes may be classified as, (i) poisonous chemical substances, *e.g.* antimony; (ii) poisonous plants; (iii) bacteria. This last group may be subdivided into (*a*) preformed toxins, *e.g. Staphylococcus* and *Cl. botulinum*; (*b*) toxins formed *in vivo*, *e.g.* Salmonella; (iv) protozoa; (v) helminths.

Most outbreaks of food poisoning occur in warm weather. Milk and milk products are susceptible to the growth of food poisoning bacteria on account of their high moisture contents and good food values. Botulism from dairy products is virtually unknown (5 cases from home canned cheese and 2 from commercially canned milk in U.S.A. from 1899 to 1941), but many cases of poisoning from *Staphylococcus* and *Streptococcus* and infections of the *Salmonella* type have occurred. The characteristics of these four types of food poisoning are summarised in Table Fo I.

TABLE Fo I

Disease	*Cause*	*Symptoms*	*Onset*
Preformed toxin			
Staphylococcus food poisoning . .	*Staphylococcus* (toxin producing)	Diarrhoea, vomiting, nausea, prostration	2 to 3 hr.
Botulism . .	*Clostridium botulinum*	Double vision, difficulty in speaking and swallowing	1 to 8 days
Infection			
Salmonella . .	S. aertrycke, S. enteritidis, etc.	Diarrhoea, abdominal pain, vomiting, prostration	½ to 3 days
Streptococcus .	α-haemolytic streptococci	Diarrhoea, nausea, abdominal pain	½ to 1½ days

Staphylococcus. Milk, cream, synthetic creams, custards, etc., are all potentially a means of staphylococcus poisoning because all milk samples contain some staphylococci, and if a cow is suffering from staphylococcal mastitis the milk may contain thousands of organisms per ml. Fortunately only a small proportion of strains are toxin producers. Usually, however, the cream, etc., becomes infected from human sources, *e.g.* from the hands of an operator suffering from boils. A period of holding at elevated temperatures, *e.g.* 70° F. or higher, is necessary to permit the growth of the bacteria and the formation of the toxin. The susceptibility of individuals to staphylococcus toxin varies considerably and not all strains of the organism produce toxin. Smell and taste usually give no indication of the presence of toxin in the food. The toxin is extremely heat-resistant but is gradually destroyed by boiling water. Usually symptoms are only evident when millions of organisms per g. are present.

Salmonella. Broadly speaking, two types of infection are caused by the *Salmonella* group: (i) the *S. paratyphi* and *S. schottmuleri* group, and (ii) the *S. enteritidis* and *S. aertrycke* group, the disease resembling typhoid fever.

Milk and cheese have been concerned in outbreaks of *Salmonella* infections. *See* Diseases, human.

Refs.: Hobbs (1953), *Food Poisoning and Food Hygiene*, London; Dack (1949), *Food Poisoning*, Chicago; Dewberry (1950), *Food Poisoning*, London; Harvey and Hill; Savage (1920), *Food Poisoning and Food Infections*, London; Wilson and Miles; Anon. (1954), *MBMH*, **13**, 12; Walder (1953), *LP*, **2**, 419, 548; Wilson (1950), *MBMH*, **9**, 148, 254; Ingram and Robinson (1951), *SAB*, **14**, 73 (botulism).

FOODS, TECHNICAL CONTROL OF. *See* Butter; Cheese; Condensed milk; Fat; Ice cream; Milk powder; Laboratories; Routine tests; Sterilised milk; Testing milk supplies; Whey.

Refs.: *FIM* (for Cereals, Confectionery, Canning and preserving, Meat products, Pickles and sauces, Food dehydration, Edible fats and fatty foods, Fruit juice products, Storage and refrigeration, Handling equipment, Packaging, Boilers); *AOAC; SMDP;* Tanner; Mojonnier and Troy; Baumgartner; Jacobs; Clayton; Winton and Winton; Blumenthal (1947), *Food products*, N.Y.; Richmond; Williams, K. A.; Cox; Nicholls; Kent-Jones and Amos (1947), *Cereal Chemistry*, London.

FOOT AND MOUTH DISEASE. This is one of the most serious diseases of cattle, being highly infectious and unpredictable in its appearance. All cattle in herds affected by the disease must be killed and the bodies burnt or buried after chemical treatment. This disease is caused by a virus and is characterised by vesicles on the mouth, feet, and udder.

A mild form of the disease may develop in humans.

Food-and-mouth disease is not endemic in Great Britain. Once this most contagious of all known diseases has obtained a foothold amongst our highly susceptible livestock, it spreads very rapidly and cannot be held in check under ordinary farming conditions. The infected animals manufacture the virus and if they are not slaughtered immediately, the disease would soon become widespread and cause great loss. Although many animals recover naturally, the disease reduces the milk supply and output of meat, and if it were allowed to run riot the cumulative effect would be very great and far exceed the cost of the slaughter policy. In Germany, where a policy of isolation and vaccination was followed in 1937-38, the disease cost £83,000,000: in this country the annual cost over the period 1941-51 was £222,000.

Slaughter is also the policy of most progressive countries, including U.S.A., Canada, South Africa, Norway, Sweden, Eire and Northern Ireland. In countries where it has not been adopted, the reason is that the number of animals affected is so large or invasion so frequent that slaughter is impracticable.

Reasons why vaccination is not feasible. (1) Vaccines are relatively expensive to produce. (2) In addition to the main types of virus there are a number of variants, and a vaccine, to be effective, must be prepared from the type responsible for a particular outbreak. Polyvalent vaccines (*i.e.* covering a number of strains) have been produced, but they are not very effective. (3) The immunity conferred by vaccines is relatively short, probably not more than six months. Re-vaccination would, therefore, be necessary at fairly short intervals. (4) A vaccinated animal might not show the lesions, but might be capable of disseminating the virus and so could be a source of danger.

Vaccination, therefore, is not a highly efficient method, but may be of some value in reducing losses where the disease is endemic, or in those countries which have land frontiers across which the infection can be readily introduced.

No figures are available to show the losses in Europe caused by the recent epidemic, but they must be very high. In England during 1951 there were 116 outbreaks, and compensation amounted to £310,284. *See* Diseases of dairy cattle.

Refs.: Miller; Wilson and Miles; Min. Agric. (1937), *Fifth Progress Report of the Foot and Mouth Disease Research Committee*, H.M.S.O.

FORCE. That which accelerates a body, or tends to change its motion. Force = mass × acceleration. The scientific unit is the *dyne*; the weight or earth-attraction of 1 g. is 980·616 dynes. *See* Definitions.

FORE MILK. The first milk to be withdrawn from the udder at the beginning of milking. There is no precise definition of fore milk but usually the first 25 to 50 ml. is so regarded. It is of poor quality chemically and bacteriologically, and should be rejected.

Refs.: Davis *et al.* (1939), *JDR*, **10**, 59 (sampling and counts); Knowles (1936), *JDR*, **7**, 63 (flora).

FOREIGN OBJECTS. A general term for insects, paper, string, caps, snails, slugs, and similar miscellaneous objects which are occasionally found in filled milk bottles. The avoidance of these is a great problem in the trade, and the best dairies employ scrutineers to pick out any faulty bottle that gets through the washing machine. It is accepted that modern washing methods will not remove such things as concrete, paint, tar, etc., but as it is virtually impossible for an unwashed bottle to get to the filler, it is often a mystery why some small and detached foreign objects appear in filled bottles.

All foreign objects in bottles are due to the misuse of milk bottles, which is an offence, but the persons responsible are only rarely summoned. A tightening-up of control on this matter would be of great benefit to dairies. *See* Legal aspects; Scrutinising.

"FOREIGNERS." *See* "Strays".

FOREWARMING. *See* Condensed milk.

FORMAGGINI. *See* Cheese, p. 192.

FORMALDEHYDE CASEIN. *See* Casein plastics.

FORMALIN. A solution containing about 40 per cent. formaldehyde H . CHO and used as a preservative for milk. Its use is now illegal (p. 601), but it is commonly used for preserving samples of milk sent away for analysis. For this purpose one drop of formalin should be added for every oz. of milk at the earliest opportunity.

In ordinary milk it is readily detected by the violet colour given with strong sulphuric acid and so is automatically detected in the Gerber test (p. 489).

FORMOL TITRATION OF MILK. Nitrogenous matter containing amino groups ($R—NH_2$) in milk, etc., can be estimated by titrating 10 ml. to the end point of phenol-phthalein, adding 1 ml. of neutralised formalin solution and re-titrating. The second titre gives a fairly accurate measure of the protein in the milk.

This method can be applied for special estimation, *e.g.* the Walker method for estimating casein (p. 166), for following the ripening of cheese and other types of proteolysis. *See* Cheese, p. 168; Kjeldahl method; Quality payment.

Ref.: Richmond.

FORMS, LABORATORY. Modern technical control in the dairy industry depends very largely on the information provided by the laboratory (Davis and Ashton (1951), *JSDT*, **4**, 78), and the planning of laboratory report forms is worth some consideration by the manager and head of the laboratory. Broadly speaking there are two types:

(i) all results of one test being written in one book;

(ii) the results for the whole dairy for one day being written on one sheet.

The former is usually the most convenient for the laboratory, and the latter for the manager. It is often advantageous for both to be used. *See* Bacteriological grading; Laboratories; Routine tests; Testing of milk supplies.

Refs.: Milk Testing; LCDP.

FORMULAE. (i) Chemical shorthand for chemical substances, *e.g.* NaCl = sodium chloride; $C_3H_6O_3$ = lactic acid. (ii) Mathematical expressions for relationships of the properties of a material. Usually certain measurable properties are equated to another property, *e.g.* fat content and gravity to solids-not-fat. *See* Fleischmann ; Richmond ; Total solids.

FOX. *See* Mammals.

FRANCE.

Ref.: Bréart (1949), *IDC*, **4**, 557.

FREE-MARTIN. A heifer calf born with a bull calf and usually barren.

FREEZE-DRIED MILK. Milk powder prepared by *in vacuo* evaporation or sublimation of water from frozen milk or frozen condensed milk. It resembles best quality spray-dried powder, and may be regarded as 100 per cent. soluble. It is by far the best milk powder, being without flavour and perfectly reconstitutable. Unfortunately it is much more expensive to make than spray-dried powder. *See* Freeze drying; Milk powder.

Ref.: Nickerson (1952), *JDS*, **35**, 77.

FREEZE DRYING. Freeze drying provides the only reliable method of preserving labile materials and consists of drying the frozen material under high vacuum, the frozen state being maintained by the heat abstracted for evaporation. The sublimed moisture is either condensed upon a refrigerated surface or chemically absorbed, leaving the pump to deal only with the small quantities of remaining permanent gases. The separate process of freezing prior to vacuum drying is inconvenient and particularly unreliable for minimal quantities which may partially melt before the application of vacuum. Auto-freezing by rapid evaporation in the drying chamber overcomes these objections, but the violent foaming which occurs under reduced pressure before freezing is completed has hitherto restricted the use of this attractive technique. As developed by Greaves of Cambridge University,[1, 2] the perfected technique employs low speed centrifuging for the complete suppression of foaming and gives a porous dried product which can be readily reconstituted.

Typical of the materials successfully dried for preservation by this method are : biological standards ; bacterial cultures ; virus suspensions ; yeasts and moulds ; hormone preparations ; pharmaceuticals ; plasma, sera, and complements ; antibiotics and other immunising, therapeutic, and diagnostic preparations for human and veterinary use.

Outline of Procedure. Generally, two stages of drying are involved : (1) primary drying which is completed in the centrifuge chamber, and (2) secondary drying and vacuum sealing on a manifold system. Centrifugation, in addition to suppressing foaming accelerates drying by forming thin frozen wedges or shells of large drying area. Centrifugation is stopped when freezing is complete and drying continued to a moisture content of less than 3 per cent.

The containers are transferred to a manifold secondary drying system for extended drying and vacuum sealing after suitably reducing the ampoule stem to facilitate subsequent closure. The apparatus is illustrated in Figs. FD 1 to 3.

Drying Times. Freeze drying times depend upon many factors,[2, 3] chiefly : the residual moisture content, the surface area exposed, the material thickness, the rate at which the material gains heat of evaporation (this latter must be

[1] Greaves (1944), *Nature*, **153**, 485.

[2] Greaves (1946), " M.R.C. Spec. Rep. Ser. No. 258 ", H.M.S.O.

[3] Bradish (1947), *Chem. Products*, Aug., p. 60.

controlled to prevent thawing). The centrifugal freeze drying technique freezes the material in the form to give large drying area and minimal depth, but beyond this the factors governing drying rates are common to all freeze drying techniques. The apparatus must be correctly designed to obtain (*a*) minimum obstruction to the flow of water vapour by the provision of wide bore pipes, (*b*) high pumping speeds, and (*c*) efficient trapping of the water vapour by refrigerated surface, or chemical desiccant. Additionally, drying times depend upon the solutes *e.g.* protein solutions require longer drying times than physiological saline. A further factor which may be dominant, in the drying times of ampoule quantities, is the small bore ampoule stem, particularly if aseptic covers, etc., impose vapour flow restrictions.

Approximate maximum drying times with minimal heating for (*a*) a 7·5 per cent. protein solution dried to below 1 per cent. moisture content and (*b*) complete evaporation of pure water, are as follows and illustrate the effect of the solute (both examples are for centrifugally freeze-dried ampoule quantities):

	(*a*)	(*b*)
0·25 c.c.	6 hr.	1 hr.
0·5 c.c.	12 hr.	2 hr.
1·00 c.c.	24 hr.	4 hr.

A residual moisture content of 1 per cent. is sufficiently low for many applications, *e.g.* short term preservation of cultures, milk, etc., but where lower values are required for long term preservation or for particular cultures, penicillin, etc., it is necessary to continue secondary drying for 24 hr. or more; because the drying rate is an exponential function of moisture content, continued loss of moisture can be demonstrated over many days vacuum drying.

Refs.: Harris (ed.) (1952), *Freezing and Drying*, Inst. Biology, London; Chambers (1949), *Trans. Inst. Chem. Eng*, **27**, 19; Proom and Hemmons (1949), *JGM*, **3**, 7 (bacterial cultures).

TABLE Fr I

FREQUENCY DISTRIBUTION OF FREEZING-POINTS

(from Stubbs and Elsdon, *A* (1934), **59**, 146)

Freezing-point depressions		*Morning samples*	*Evening samples*	*Unknown samples*	*Total samples*
from 0·529	to 0·530	2	3	1	6
0·531	0·532	2	2	–	4
0·533	0·534	10	9	1	20
0·535	0·536	14	21	1	36
0·537	0·538	31	36	1	68
0·539	0·540	43	67	11	121
0·541	0·542	53	61	11	125
0·543	0·544	62	83	12	157
0·545	0·546	68	65	6	139
0·547	0·548	48	55	6	109
0·549	0·550	39	39	5	83
0·551	0·552	23	26	2	51
0·553	0·554	11	21	2	34
0·555	0·556	13	9	1	23
0·557	0·558	7	1	–	8
0·559	0·560	9	1	–	10
0·561	0·563	5	1	–	6
		440	500	60	1000

These samples were considered to be genuine.

FREEZING-POINT TEST. This is the only reliable test for the adulteration of milk by water. The freezing-point of any solution is proportional to its *osmotic pressure* or the concentration of dissolved particles. The osmotic pressure and so the freezing-point of milk is controlled chiefly by the salts and lactose in milk and is remarkably constant. Addition of water will lower the osmotic pressure, and so alter the freezing-point, and as the amount of altering of the freezing-point is proportional to the amount of water added, the freezing-point of milk gives a fairly accurate measure of the amount of water added. Many factors such as mastitis, breed, season, feed, etc., can alter the concentrations of the various constituents of milk but such alteration does not affect the osmotic pressure. *See* Fallacies; Chloride-lactose ratio.

The freezing-point of the milks of individual cows has been found to vary from − 0·53° to − 0·56° C., with an average of − 0·544° or − 0·545° C. (Table Fr I). Obviously the greater the number of cows considered, *i.e.* the greater

TABLE Fr II

FREQUENCY DISTRIBUTION OF FREEZING-POINT DEPRESSIONS OF BULK MILK, 1942 to 1947
(from Macdonald, *A* (1948), 73, 423)

°C.	*No. of samples*					
	1942	1943	1944	1945	1946	1947
0·498 to 0·520	1				3	1
0·523	1				1	—
0·524	2				—	—
0·525	2				1	—
0·526	2			1	—	—
0·527	4	2	3	—	—	—
0·528	4	1	—	2	—	1
0·529	6	1	2		1	1
0·530	12	2	4	1	2	2
0·531	10	2	—	—	1	2
0·532	8	2	4	5	2	—
0·533	13	3	2	1	5	2
0·534	17	9	2	2	10	2
0·535	23	7	2	4	10	4
0·536	31	15	3	4	20	1
0·537	31	18		1	10	4
0·538	37	18	1	3	4	—
0·539	53	33	17	15	63	50
0·540	77	70	123	155	187	166
0·541	59	51	109	167	172	139
0·542	66	85	270	366	304	252
0·543	67	152	558	524	463	337
0·544	67	167	547	438	440	412
0·545	48	142	99	45	162	267
0·546	50	153	45	21	80	134
0·547	43	110	43	11	23	50
0·548	46	112	37	8	10	6
0·549	12	113	16	3	1	6
0·550				—	4	1
Total .	792	1268	1887	1777	1979	1840

These figures illustrate the progressive improvement in the purity of bulk milk supplies sampled over a wide area.

the bulking of the milk, the nearer will the measured freezing-point of the milk approach this average value (Table Fr II). As − 0·53° C. is the smallest *depression* recorded on genuine milk, this is taken as the standard for control purposes. In other words, any milk found to have a depression less than 0·53° C. (*i.e.* a freezing-point between − 0·53° and 0° C.) can safely be considered to contain added water. Recent work has suggested that on rare occasions a herd meal may have a depression less than 0·53° C. (Hillman *et al.* (1950), *CI,* 333). This may be related to the absence of drinking by the cows during the night (Aschaffenburg and Rowland (1950), *CI,* 636). Similar results have also been reported by Williams and Ellis (1953), Munic. J. Lond. No. 3139, 757). In America Shipe *et al.* (1953, *JDS,* **36,** 924) have found statistically significant differences between breeds, methods of feeding, and morning and evening milks. They obtained an average depression of 0·539° C., the range for genuine individual cow samples varying from 0·513 to 0·565° C.

The freezing-point test has no statutory basis, but evidence on this point can be accepted in a court of law to support other evidence, *e.g.* low solids-not-fat.

Although the accusation of adulteration is usually indignantly denied by producers and others, it must be remembered that no one can deny that water has been added unless the milk has been under continuous observation from the time it leaves the cow. Adulteration is often innocently done and quite unrealised by the farmer himself or by those subsequently handling the milk.

The test itself is one requiring the greatest care not only in the technique itself, but in the calibration of the apparatus and especially the thermometer. This should preferably be calibrated at the National Physical Laboratory and should be checked not only at the temperature of melting ice (0° C.) but also at the working range (− 0·52 to − 0·56). These temperatures are sometimes checked by making tests with sucrose solutions (7, 8·5, and 10 per cent.), but these are not reliable at a concentration above 8·75 per cent. In careful hands, the method should not have an error greater than ± 0·002° C. corresponding to ± 0·4 per cent. added water.

Temple (1937, *A*, **62,** 709) has described a refrigerated unit and Shipe *et al* (1953, *JDS,* **36,** 916) a still further mechanised form of the original Hortvet apparatus.

The test is not yet legal in this country, although there has been a trend of thought in this direction. Problems which have to be settled are : (i) standardisation of apparatus ; (ii) standardisation of method ; (iii) standards for genuine milk.

It is possible to work to a finer precision with bulk milk than with farmers' supplies because of the equalising of extreme values, but the adoption of different standards for farm and bulk supplies would lead to legal difficulties.

Refs.: Davies ; Richmond ; Lythgoe (1952), *JAOAC*, **35**, 855 (sour milks); Aschaffenburg and Hall (1949), *A*, **74,** 380; Macdonald (1948), *A*, **73,** 423 (bulk milk) ; Dept. Health Scot. (1945), " The Freezing-point (Hortvet) Test of Milk " (good review and bibliography). H.M.S.O. ; Aschaffenburg and Veinoglou (1944), *JDR*, **13,** 267 (various factors) ; Aschaffenburg *et al.* (1944), *JDR*, **13,** 281 (survey of producers' milks) ; Aschaffenburg and Temple (1941), *JDR*, **12,** 315 (cow's milk throughout lactation) ; Stubbs and Elsdon (1934), *A*, **59,** 146.

FREQUENCY. The number of complete oscillations or vibrations per sec. in a current or vibrating material or medium.

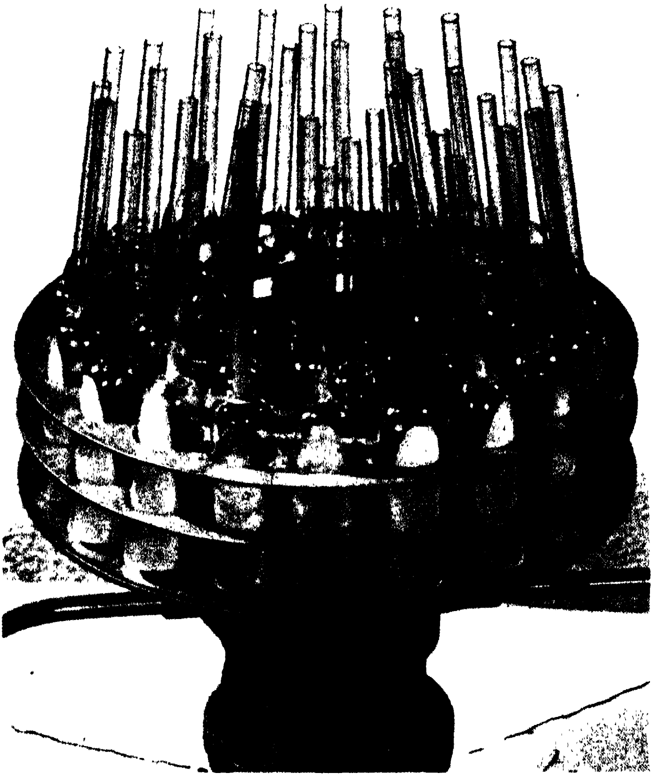
FRESHENING. The onset of calving.

FRITZ PROCESS. *See* Butter-making machines.

FROST LITTLE PLATE METHOD. A miniature and quick method for making a plate count of milk. *See* Microscopic count ; Plate count.

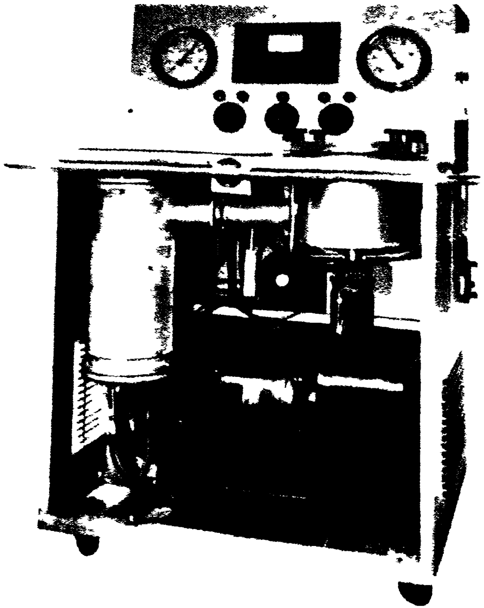
Refs.: Chalmers ; Hammer ; Wilson *et al.* ; Barkworth (1936), *JDR*, **7,** 244.

FROTHING. *See* Foaming.



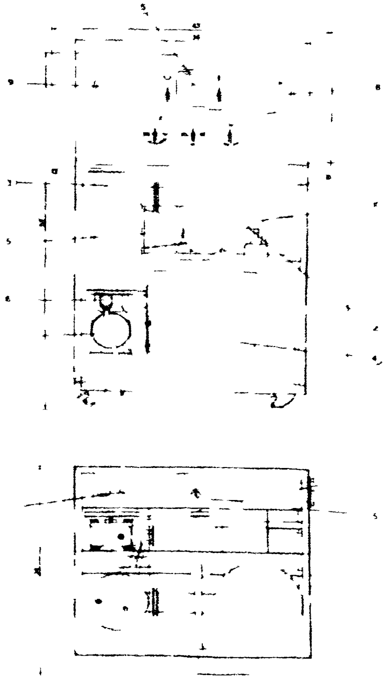
[*By courtesy of F. W. Edwards & Co. Ltd.*

FIG. FD 1.—*Centrifuge Head (demounted from Drying Chamber) Loaded with Ampoules. Note the Wedges of Freeze Dried Materials in the Ampoules.*



[By courtesy of W Edwards & Co

FIG FD 2 —*Commercial Centrifuge Freeze Drying Unit Complete with Vacuum Pumps Gauges and Allied Components and in which a Mechanically Refrigerated Surface Condenses the Sublimed Moisture from the Frozen Ampoule Contents*



[By courtesy of W Edwards & Co

FIG FD 3 *Outline Diagram of the Unit illustrated in Fig FD 2.*

(1) *Primary Drying Chamber and Centrifuge*
(2) *Centrifuge Motor and Rotary High Vacuum Seal*
(3) *Refrigerated Water Vapour Condenser*
(4) *Refrigeration Unit*
(5) *Pirani Vacuum Gauge*
(6) *Vacuum Release Valve and Defrosting Drain Cock*
(7) *Primary Drying System Single Stage Pump*
(8 and 9) *Primary Drying Chamber and Condenser Thermometer.*
(10) *Secondary Drying System, Two Stage Pump*
(11) *Secondary Drying Manifold (Mounted at Rear of Unit)*
(12) *Secondary Drying Headers and Isolation Valves*

FROZEN CONCENTRATED MILK. Milk from which two-thirds (or some similar proportion) of water has been removed and which is then frozen. *See* Freeze-dried milk.

Ref.: Davis (1951), *SAB*, **14**, 216.

FROZEN MILK. Under certain conditions milk can be frozen and so preserved for a long time. Milk has been safely taken on long sea voyages in this condition. The disadvantages are: (i) expense; (ii) ice separates first so that on thawing, part of the milk may be low in solids; (iii) the thawed milk may be "sandy" due to precipitation of casein and phosphates.

See Refrigeration.

Refs.: Davis (1952), *F*, **21**, 467; Davis (1951), *SAB*, **14**, 216; Bell and Mucha (1952), *JDS*, **35**, 1; Babcock *et al.* (1952), *JDS*, **35**, 195; Tracey *et al.* (1950), **33**, 832; Mucha and Bell (1951), *JDS*, **34**, 953; Bell and Mucha, *ibid.* 432; Wildasin and Doan (1951), *JDS*, **34**, 438.

FRUIT FLY. *See* Insecticides.

FUMIGATION. *See* Insecticides.

FUNGI. In dairying this term usually means moulds. The classification of those of importance in dairying is given in Table Mo 1 (p. 749). *See* Moulds.

FUSARIUM. A mould sometimes found in mouldy butter. *See* Moulds.

FUSIFORMIS. A genus of bacteria characterised by long, filamentous cells of irregular shape. The type species is *F. necrophorus*, the causative organism of calf diphtheria.

Refs.: Bergey; Miller; Wilson and Miles

G

GALACTANS. A gum-like carbohydrate material formed by certain bacteria and a cause of ropiness in milk (p. 932).

GALACTASE. The old classical name for the proteolytic enzyme in milk. It was formerly thought to play an important part in the ripening of cheese, but this theory is now discredited.

GALACTOSE. A hexose forming half the molecule of lactose (p. 600).

GALLON. The volume of 10 lb. of water at 62° F. and equal to 0·16054 cu. ft., 277·3 cu. in., or 4·546 l. The *American gallon* is appreciably less, one British gal. equalling 1·20094 American. *See* Weights and Measures.

GAMMELOST. *See* Cheese, p. 192.

GARGET. A name for mastitis (p. 659), used by farmers. *See* Abnormal milk.

GARLIC. *See* Flavours.

GASES. (i) ***In milk.*** Milk in the cow's udder contains about 10 per cent. by volume of CO_2. During milking this drops to 4 to 5 per cent. accounting for the froth in the milk pail. A further fall to about 3 per cent. occurs during the first few hours, the oxygen and nitrogen of the air gradually entering during this time. Later the growth of bacteria leads to an increase in the CO_2 and a decrease in the oxygen content. This gradual loss of CO_2 causes a slight decrease in titratable acidity, which is attributed by some practical dairymen to aeration (*see* Fallacies, p. 457). The loss in CO_2 also causes a slight rise in density and part of the Recknagel change (p. 889) is due to this.

Bacterial growth can result in the production of gases as the result of biochemical activity, the most important being CO_2. Heating milk to 80° C. or higher results in the production of traces of hydrogen sulphide by decomposition of the sulphur-containing amino acids of the albumin.

(ii) ***In cheese.*** Holes in cheese are produced by bacterial fermentations, propionic acid bacteria in Emmenthal cheese (p. 192), and the heterofermentive lactic acid bacteria and coliforms in other types where the holes constitute a defect (p. 180).

(iii) ***In condensed milk.*** The "blowing" of tins of condensed milk (p. 277) is usually due to the growth of yeasts resulting from contamination of the tins or the coolers.

Ref.: Rogers.

GAS PACKING. *See* Milk powder.

GAS RATIO. *See* Coliforms.

GASTRO-ENTERITIS. *See* Food poisoning.

GAULIN HOMOGENISER. *See* Homogenisation.

GEL. This term is applied loosely to any jelly-like material, but a strict definition is still a matter for controversy; scientifically it refers to a colloidal solution in which the particles have precipitated; the coagulum in cheesemaking (p. 168) is an excellent example. Some writers apply the term to any solution (p. 961) which has measurable rigidity. *See* Rheology.

GELATINE. A protein prepared by boiling collagen (the main protein of white fibrous tissue) with water. This change, an intramolecular rearrangement rather than a hydrolysis, makes the protein more digestible. Before the introduction of agar, gelatine was commonly used for solid bacteriological media, but could only be used at 22° C. or below. It is rich in glycine, proline, and hydroxyproline. *See* Ice cream; Media.

GELATINE LIQUEFACTION. One of the most important diagnostic properties of bacteria. *See* Classification; Coliforms; Lactic acid bacteria.

GENERATION TIME. In bacteriology the time taken for the doubling of a bacterial cell. It is usually calculated by making bacterial counts after times t_1 and t_2; if these are n_1 and n_2 then the number of generations is

$$\frac{\log n_2 - \log n_1}{\log 2} = N_G \text{ and the generation time} = \frac{t_2 - t_1}{N_G}.$$

The shortest generation times naturally occur under the most favourable conditions, *viz.* optimum temperature, usually between 35° and 45° C., a favourable medium such as milk or broth, and relatively few organisms. The average times for bacteria of interest in dairying under optimum conditions are as follows:

	Min.
Coli-aerogenes	15 to 20
Bacillus	15 to 20
L. thermophilus	15 to 20
Salmonella	20 to 30
Proteus	20 to 30
Streptococcus	25 to 35
Staphylococcus	25 to 35
Pseudomonas	30 to 40
Corynebacterium	35 to 40
Clostridium	35 to 50
Lactobacillus	40 to 80

Ref.: Buchanan and Fulmer; Wilson and Miles.

GERBER TEST. *See* Fat.

GERMANY.

Refs.: Vopelius (1949), *IDC*, **5**, 178; Hensler, 188; Schulz (1952), *Dairy Lexicon* (in German), Kempten, Allgaü; Reichart *et al.* (1937), *The Present State of the German Dairy Industry*, Berlin.

GERMICIDAL ACTION OF MILK. As milk is derived from blood, it is not surprising that milk contains substances which tend to kill or stop the growth of bacteria. These include agglutinins which cause bacterial cells to clump together, precipitins, bacteriolysins which cause bacteria to disrupt, and opsonins which have the effect of making bacteria less resistant to attack by leucocytes or white blood cells.

The evidence for the presence of these substances (antibodies) is very controversial but it is generally accepted that there are substances in milk which restrain bacterial growth for about 6 hr. at 37° C. and longer, possibly up to 24 hr. at lower temperatures. These are, however, so feeble that they play no significant part in the preservation of milk but probably help to protect suckling animals. Colostrum is much richer in these antibodies than normal milk. *See* Bactericidal; Bacteriostatic; Lactenin.

Ref.: Berridge (1954) (in press); Marrack (1947), *Brit. Med. Bull.*, **5**, 187.

GERMICIDES. *See* Disinfectants.

GEROME. *See* Cheese, p. 192.

GERVAIS. *See* Cheese, p. 192.

GESTATION. The period of pregnancy of the cow. Gestation depresses the milk yield by about 20 per cent. compared with a farrow cow. *See* Management of cattle; Milk secretion.

GHEE. Ghee is the name given in India to butter from which the water has been driven off by heat, and can be made from fat from the milk of the cow, buffalo, goat, or sheep. Ghee has the same chemical constitution as butterfat except that the Reichert value (p. 901) may be low.

Refs.: Davies; Richmond; Williams, K. A.; Davies (1949), *Indian Indigenou Milk Products*, Calcutta; Godbole and Sadgopal (1939), *Butter Fat* (ghee), Allahabad; Lalitha and Dastur (1953), *IJDS*, **6**, 147 (K.Q.); Bhattacharya and Hilditch (1931), *A*, **56**, 161.

GILL. Five fluid oz. = 142·07 ml.

GIODDU. A name for Yoghurt in Sardinia.

GLANDS. Certain cells of the body, in addition to carrying out the metabolic processes necessary for their own existence, manufacture from the blood specific substances which they pass out from themselves to serve some physiological purpose elsewhere in the body. These cells are termed *glandular* cells. Organised collections of such cells are termed *glands*.

Endocrine Gland. An *endocrine* gland or a gland of *internal secretion* is a gland which pours its elaborated product (a hormone) into the blood or lymph, *e.g.* the thyroid gland.

Exocrine Gland. An *exocrine* gland or a gland of *external secretion* passes its products through a duct or ducts to the outside of the body (*e.g.* mammary gland) or into a cavity communicating with the exterior (*e.g.* salivary gland).

GLASS. This is used for bottles (p. 80). Although the fragility and heat-breakage are disadvantages, the resistance to acids and alkalis, etc., is a big advantage and the glass milk bottle is still the best returnable container for milk. The so-called " glass-lining " of road and rail tankers and storage tanks is really enamel. However, stainless steel tanks are steadily ousting all other types for bulk transport (p. 130). *See* Bottles; Pipe lines.

GLASS ELECTRODE. The most useful type of electrode for measuring the acidity of milk and milk products. *See* Acidity; Hydrogen ion concentration; Quinhydrone electrode.

Refs.: Britton; Clark; Dole (1941), *The Glass Electrode*

GLOBULES. *See* Fat globules.

GLOBULIN. The less important quantitatively of the whey-soluble proteins in milk. It differs from albumin in being insoluble in distilled water but is soluble in dilute solutions of salts and mineral acids. It appears to consist of two proteins —euglobulin and pseudo globulin, the former being of importance in cream-line behaviour. *See* Albumin; Constituents; Cream-line; Whey.

Refs.: Richmond, Davies; Rogers; Marsden (1953), *DSA*, **15**, 167

GLOUCESTER. *See* Cheese, p. 193.

GLUCOSE (DEXTROSE, GRAPE SUGAR). A hexose sugar of the formula $C_6H_{12}O_6$ which constitutes with galactose the molecule of lactose.

It is the sugar present in blood and is the precursor of milk sugar.

GLYCERIDES. The chemical name for fats which consist of mixed glycerides or esters (p. 455) of glycerol and fatty acids (p. 462). *See* Fats.

GLYCEROL. A trihydric alcohol $CH_2OH\,.\,CH(OH)\,.\,CH_2OH$ which is the basis of all natural fats (p. 459) or glycerides. It is also produced as a by-product and as an intermediate in some fermentations.

Refs.: Mikkelsen (1948), *A*, **73**, 447 (estimation); Stephenson.

GOAT MILK. Although relatively rare in this country, goats contribute an important fraction of the milk supply in some countries, especially round the Mediterranean Sea. A good average yield is 3 to 4 pints a day and the milk is somewhat richer than average cow's milk. The calorie value is about 72 per 100 ml. and goats' milk is positive to the alcohol test. Goats are very resistant to tuberculosis but the chemical nature of goat milk fat tends to give the milk a characteristic odour. *See* Mammals.

Refs.: Phillips (1942), *Goats*, Colchester; Holmes (1941), *Family Goat Keeping*, Colchester; Davies (1920), *Goat Keeping for Milk Production*, London. Golberg and Hadland (1953), *IDC*, **3**, 1287 (det. cow milk in goat milk); Nesem and Fremuth (1952), *M*, **7**, 113; Seidler (1951), *M*, **6**, 170 (composition).

GOAT'S MILK CHEESE. *See* Cheese, p. 193.

GOLDING METHOD FOR FAT. A neat and simple gravimetric method in which the fat is separated in the presence of ammonia, butyl and ethyl alcohols, removed and weighed. *See* Fat.

Ref.: Golding (1937), *JDR*, **8**, 275.

GORGONZOLA. *See* Cheese, p. 193.

GOTHMAN PROCESS. An early type of roller drier consisting of a spirally-corrugated conical drum engaged with a similarly corrugated surface. *See* Milk powder.

GOUDA. *See* Cheese, p. 195.

GOVER'S PROCESS. A type of vacuum roller drier with two drums operating on the ordinary principle. *See* Milk powder.

GRADING OF DAIRY PRODUCTS. Cheese. The grading of cheese is comparatively new in this country, and very little was done in this direction until about 1930. The present Ministry of Food scheme is not the first attempt, for as far back as 1928-31 the Ministry of Agriculture introduced The Agricultural Produce Grading and Marketing Acts to enable the Ministry of Agriculture and Fisheries to make regulations prescribing grade designations and grade designation marks for any kind of agricultural produce. This act defined the quality indicated by such grade designations.

When such designated produce was sold it was deemed to be a term of contract of sale that the quality of the article should accord with the definition of quality applicable to such grade designation. This scheme did much to improve the quality of home-produced cheese and the price incentive was an important factor in the economics of cheese production.

During the early part of World War II the National Market Scheme was discontinued, and in 1941 the present grading scheme introduced. The introduction of rationing and the control of milk and cheese made some method of quality control necessary both from a production as well as from a distributive point of view. Grading was necessary to ensure that the cheese was of marketable quality, and also to deal with cheese unfit for the ration in its present state. An attempt was made to produce a uniform cheese of the Cheddar type and this appeared to be the most suitable, as it possessed good keeping quality, was firm to handle and cut, and was not so liable to damage during transport as some of the territorial varieties. As a rationed article it was absolutely necessary to have some uniformity in the method of manufacture and the "territorial" varieties were adjusted to give a cheese of fairly uniform type In other words, an attempt was made to "cheddarise" all varieties.

Coloured home-produced cheese disappeared from the market and were not reintroduced until after the war.

Description of scheme. The premises and equipment of each maker are inspected and if they are up to the required standard the maker is registered and allotted a Registration Number.

The milk is supplied to the maker by the Ministry of Food through the Milk Marketing Board and charged to him at 8d. per gal.

The cheese are graded according to variety, Dunlop, Cheddar, Derby and Leicester cheese when 28 days old, and Cheshires, Lancashires and Wensleydales when 14 days old.

The maker must keep each day's cheese separate, and if making several vats must record the following information: (1) date of manufacture; (2) vat number; (3) registration number. By this means a cheese can be traced back to the maker in case of any dispute. The maker must keep records of (1) quantity of milk used daily; (2) variety of cheese made; (3) number of cheese made each day.

The grader on arrival at the creamery inspects the cheese of the necessary age for general appearance, conformity to type, methods of storage, etc. He will then iron a cheese from each vat and examine this carefully for body, colour, texture, flavour, etc., and from this information decide on the grade.

Grade I cheese must be true to type, show no signs of external damage, must be sound and of good keeping quality, and clean in flavour. *Grade II* cheese must be good sound cheese, but not necessarily of long keeping type. They must in any case be of good flavour and fit for distribution as a ration. *Grade III* are not considered fit for the ration, may leak, be damaged, off-flavoured and of inferior keeping quality. This grade is sent to processors for the production of processed cheese, and is quite suitable for the purpose when blended with other cheese, either imported or home made. The fourth grade is known as *No Grade*, and is not stamped by the grader. Such cheese is used for the manufacture of poultry foods, etc.

Each cheese of Grade I quality is stamped with the appropriate mark bearing the number 1. Grade II is similarly marked, but bears the number 2. The Grade III stamp not only carries the number 3, but has a diagonal cross, and is thus readily distinguished from Grades I and II.

Special non-poisonous red ink is used for all markings. The stamps of each grader are individually marked with a letter on either side of the number, so that if any dispute arises the cheese can be traced back to both the maker and the grader. Having completed the marking, the grader issues four copies of a grading certificate giving the following information: (1) Name of maker or creamery; (2) Maker's registration number; (3) Variety of cheese; (4) Whether farm-house or creamery production; (5) Month of manufacture; (6) Number of cheese graded of each month's make; (7) Factor to whom the cheese is consigned; (8) Name of the grader.

The grader signs the certificates and records the date of grading. The maker or his representative also signs the certificates and acknowledges that he agrees with the grading. All four copies are then handed to the maker, who in turn sends them, together with the cheese, to the factor.

The factor examines the cheese on arrival, checks the number, and weighs them, after which he posts one copy of the certificate to the maker, one to the Ministry of Food, London, one to the Area Distribution Officer, and retains one himself.

Care has to be taken to keep each month's make separate at all stages, and weights have to " key up " with the number of gallons of milk used.

The price paid by the Ministry of Food for the different varieties of cheese varies slightly, and this, in turn, is related to the average number of gallons taken to make 1 cwt. of cheese. Cheddar, being of longest keeping quality has a higher gallonage per cwt. factor than Cheshire, Wensleydale or Lancashire, which may be graded when only 14 days old. The price received for 2nd Grade cheese is always 5s. per cwt. less than 1st Grade of any variety. Third Grade realises 10s. per cwt. less than 1st Grade. Cheese in the " NO GRADE " category is paid for at realisation value less expenses. The margin of profit is small, but a maker who gets 95 per cent. 1st Grade produce will get a fair remuneration. After the cheese has been taken over by the factor, the Ministry sends to the maker full details of the transaction, together with price, and a cheque is passed for this amount.

A factor is really acting as an agent of the Ministry of Food, and receives cheese in such quantities as are directed by the Ministry of Food. He is paid for weighing and storing the cheese, and also a further sum for weighing out and despatching cheese to the retailer.

A factor's stores are subject to Ministry of Food inspection and, in case of complaint as to the quality of cheese received, a grader visits his premises, inspects the cheese, and if in his opinion this has deteriorated since grading, he may re-grade a consignment and send a report to the Ministry of Food. A factor has his own registered customers whom he can supply with their entitlement of cheese after release by the Ministry of Food.

Should a grocer send in a complaint about the quality of a consignment, a grader has to visit the premises, examine the cheese and report to the Ministry of Food.

Should the grader consider a particular consignment has deteriorated to such an extent as to be unfit for the ration, a further consignment will be sent to the grocer, together with instructions as to the disposal of the inferior cheese. In this case the loss is borne by the Ministry of Food.

All cheese are paid for at the original grade rate, and the maker has no further responsibility once he has passed his cheese to the factor. An allowance for carriage from the maker's premises to the store or factor's premises is made by the Ministry of Food.

Should the weight of cheese produced from a known quantity of milk be either excessively high or low, enquiries are made as to the reason for this. Every effort is made to encourage the production of sound, good keeping cheese, and any effort to get big weight by the retention of excessive moisture discouraged. Should a maker consistently produce low grade cheese the Ministry has the right to reduce the volume of milk supplied, and in extreme cases stop the supply of milk altogether.

See Bacteriological grading; Butter; Cheese; Condensed and evaporated milk; Legal aspects; National Milk Testing Scheme; Quality payment.

Ref. : Thomson (1925), *Grading Dairy Produce*, London.

GRAIN. (i) A weight equal to 0·0022857 oz. av. or 0·0648 g. (ii) In butter-making the size of the butter particles after the emulsion has " broken ".

GRAM OR GRAMME. The weight of 1 c.c. of water at 4° C. or 1 ml. at 15° C. It is equal to 15·432 grains or 0·03527 oz. av.

GRAM-NEGATIVE BACTERIA IN MILK. *See* Classification.

Refs. : Abd-el-Malek and Gibson (1952), *JDR*, **19**, 294.

GRAM STAIN. *See* Classification.

GRASS. Grass is the natural food of the dairy cow, and of some 25 million acres of farm land in Great Britain, 16 million were down to permanent pasture in 1939 (*see* Agriculture). Grass land consists of pastures (for grazing) and meadows (for hay) and the proportion of these to arable land varies with climate and soil, being higher in the west and north-west. Grass is favoured by low altitude, high but not excessive rainfall, and deep, rich soil. In practice, grasses never grow in " pure culture " but are always accompanied by clovers and weeds. About 14 species of grass are common in this country and these may readily be identified in summer when in flower. The feeding value of a grass is, perhaps, best measured by the protein content, as this controls the body-building power of a food, and about 6 of the 14 common species may be considered first-class, *viz.* cocksfoot, crested dogstail, Italian rye grass, perennial rye grass, stalked meadow grass (rough and smooth), Timothy. A leafy grass is more valuable than a stemmy grass and young grass is richer in protein than old grass.

A number of factors decide the *usefulness* of a grass, as distinct from its *quality*, and these are leafiness, palatability, persistency, " winter greenness " (ability of green leaves to survive), length of grazing season, resistance to drought, and recovery after hard grazing. Aggressiveness is an undesirable feature since a too aggressive grass may smother the slower-growing grasses at certain times of the year.

The clovers form a most important part of pasture, because they are legumes and have on their roots nodules with cultures of nitrogen-fixing bacteria. Clovers are also richer in protein and minerals than grasses and most weeds. These three properties make clovers a most valuable constituent of the sward. The best clovers are wild white clover and broad red clover.

Weeds are not deleterious provided (i) they are not dangerous to cattle; (ii) they will not impart taint to the milk; (iii) they occupy only a small proportion of the total herbage.

The art and science of pasture and meadow management consist of arranging grazing, resting, cutting, and manuring to give the highest yield of good grass and keep the sward in good condition and a proper balance between the grasses. Mixed grazing is best for grassland; sheep and horses denude the turf of the finer grasses. In addition to dung, grassland may require dressing with sulphate of ammonia (for early and late grazing), superphosphate (to encourage the clovers), potash (for sandy and heavy soils), and lime (for acid soils). Good drainage is essential as waterlogged soil does not permit the development of the roots. *See* Agriculture; Feeding.

Refs.: Davies (1952), *The Grass Crop;* Petersen; Castle (1951), *DSA*, **13**, 399.

GRASS DRYING. This method of preserving grass for winter feeding is a recent development. The equipment and methods of drying are still in the experimental stage, but there is general agreement that good quality dried grass is a first-class food that can replace " concentrates " in winter. The grass should be cut when young (when the protein content is high) and immediately dried to a moisture content of 5 per cent. A mobile grass-drier is now available. The cost of drying is about £16 per ton of dried grass. *See* Agriculture; Feeding; Grass.

Refs.: Watson (1938), *Feeding Artificially Dried Grass*, London; Cheveley (1937), *Grass Drying*, London; Dixey and Askew (1937 and 1938), *Grass Drying: A Study of Production Costs in* 1936, Oxford; D.S.I.R. (1952), *Bibliography of Industrial Drying*, H.M.S.O.

GRASS TETANY. *See* Addendum, p. 1132.

GRASSY FLAVOUR. A taint attributed to cows feeding on certain grasses or on rank grass.

GRAVITY. *See* Density.

GRAZING. *See* Agriculture; Feeding; Grass; Management of cattle.

Ref.: Castle *et al.* (1950), *JDR*, **17**, 215.

GRAZING, EFFECT ON COMPOSITION OF MILK. Properly-controlled experiments on this problem are few in number and the results often contradictory. There seems to be some evidence that turning cows out to grass results in a slight fall in fat and a slight rise in solids-not-fat, but in practice other factors are also exerting an effect, *e.g.* climate, the adequacy of the pre-grazing diet, etc. The war years (1939–45) in which a shortage of concentrates in winter was experienced, have led to the conclusion that the solids-not-fat can rise by as much as 0·2 per cent. when cows are turned out to grass in April or May. *See* Composition, factors affecting; Feeding.

" GREEN " CHEESE. *See* Cheese, p. 195.

GRIESS AND GRIESS-ILOSVAY TESTS. Of these two tests for nitrites, the latter is more sensitive. *See* Classification.

GRITTINESS. A fault in cheese which may be due to the precipitation of calcium phosphates and citrates, and the crystallisation of amino acids, the latter occurring in old Cheddar cheese.

In condensed milk, " grittiness " or " sandiness " is due to allowing too large crystals of lactose to form. *See* Condensed milk.

GROWTH OF BACTERIA. The three most important factors controlling the growth of bacteria are warmth, moisture, and the presence of suitable foodstuffs. Even in the presence of these favourable conditions, bacteria will not grow if adverse factors are present. In dairying, the most important of these are acidity (as in cheese), high salt concentrations (as in salted butter and cheese), high sugar concentrations (as in sweetened condensed milk), chlorine (as in chlorinated water and in chlorinated rinse tanks), high alkalinity (as in the detergent section of bottle-washing machines), low surface tension (as in modern detergents incorporating wetting agents).

These factors are summarised in Table G I.

TABLE G I

SUMMARY OF FACTORS CONTROLLING BACTERIAL GROWTH

Temperature	Most favourable over the range 70° to 100° F. (21° to 38° C.)
Moisture	Always favourable
Foodstuffs	Essential
Cold	Slowly kills or no effect in region 30° to 35° F.
Heat	Kills in region 55° to 65° C. (130° to 150° F.)
Light	Unfavourable ; can kill. Blue light most effective.
Ultra-violet rays	Strongly lethal
Electricity	Lethal effect apparently due to heat generated
Desiccation	Slowly kills or no effect
Acids	Lethal below *p*H 4 to 5
Alkalis	Variable ; some types survive *p*H 10 or higher
Salt solutions	Stimulate in range 1 to 2 per cent. ; depress and kill over range 5 to 15 per cent.
Heavy metal salts	Usually toxic in very low concentrations

Broadly speaking, moulds are more resistant to acids and physical factors than bacteria. Spores of bacteria are highly resistant to all lethal factors. *See* Classification ; Lactic acid bacteria ; Media ; Stability ; Thermoduric bacteria ; Thermophilic bacteria.

Refs. : Bergey ; Buchanan and Fulmer ; Chalmers ; Cunningham ; Wilson and Miles.

GRUYÈRE. *See* Cheese, p. 195.

GUERNSEY. The most popular of the Channel Islands' breeds in this country. *See* Breeding ; Channel Islands' milk ; Quality payment.

Ref. : Caldwell (1941), *The Guernsey : A Portrayal of the Advancement of Guernsey Cattle in America*, Peterborough, N.H.

GUMS. Gums are viscous, adhesive, complex polysaccharides, or carbohydrates. Certain bacteria can produce gums in milk and so cause ropiness (p. 932).

Ref. : Rogers.

GYNOLACTOSE. A sugar which has been reported to exist in human milk. Properties : M.P. 205 C. ; $[\alpha]_D$ - 27 ; hydrolysis yields dextrose and galactose ; Selivanoff test negative. *See* Allolactose.

Refs. : Davies ; Richmond.

HAEMOLYSIS. The lysis or dissolving of the red blood corpuscles. The chief interest from the dairying point of view is the presence of bacteria in milk capable of haemolysing blood in blood agar. Haemolytic power is to some extent correlated with pathogenicity but there are many exceptions. *See* Haemolytic streptococci ; Media.

Refs. : Wilson and Miles ; Davis and Rogers (1939), *JH*, **39,** 446.

HAEMOLYTIC STREPTOCOCCI. Many pathogenic streptococci have the power to destroy the red blood corpuscles and so produce zones of clearing or haemolysis round their colonies. This property separates them from the typical dairying types such as *Str. lactis* but there are species producing partial haemolysis (α′) and greening (α) on blood agar (*see* Classification and Media).

The haemolytic streptococci are responsible for some well-known infections or diseases (p. 396) and may be classified in two ways—the old, broad empirical method and the modern serological way according to the special techniques of the precipitin reaction evolved by Lancefield. These are summarised in Table Ha I.

TABLE Ha I

CLASSIFICATION OF THE HAEMOLYTIC AND OTHER STREPTOCOCCI

Lancefield group	*Species names*	*Reaction on blood agar*	*Diseases caused*	*Virulence*
A	*Str. pyogenes* or *Str. haemolyticus*	β	Septicaemia, scarlet fever, septic sore throat, erysipelas	High
B	*Str. agalactiae* or *Str. mastitidis*	Weak β or nil	Mastitis	Variable
C	*Str. equi* (part) *Str. dysgalactiae* (?)	β	Lesions in animals, mastitis	High
D	*Str. faecalis* or *Str. faecium*	α′ or nil	Endocarditis	Low
E		β	—	Nil
F		β	Sore throat	Low
G		β	Tonsilitis	Low
H		β		Nil
K		β		Nil
L				
M				
N	*Str. lactis* (?)			
	Str. viridans or *Str. salivarius*	α	Septic teeth, sore throat	Low
	Pneumococcus	α	Pneumonia	High

See Classification ; Diseases, human ; Diseases of dairy cattle ; Lactic acid bacteria ; Mastitis.

Refs. Sherman (1937), *BR*, **1,** 1 ; Wilson and Miles ; Rammelkamp and Dingle (1948), *ARM*, **2,** 279.

HALOGENATED CASEIN. Many compounds have been prepared by the action of chlorine, bromine, and iodine on casein. Their formulae are not known and probably a variety of compounds is produced. The halogen apparently enters the ring of the aromatic amino acids. The most important is *iodocasein*, which is prepared by the action of iodine on casein at 100° C. and treating the periodocasein with thiosulphate to reduce the iodine from 17·8 to 5·7 per cent. Iodocasein is a white powder which behaves as an acid like casein, contains phosphorus and sulphur and is insoluble in neutral organic solvents. It has recently been found to be of great use as a source of iodine for dairy cattle. *See* Feeding ; Hormones ; Milk secretion.

Refs. : Davies ; Rogers.

HAMMARSTEN'S CASEIN. Casein prepared by Hammarsten's method which is as follows :

Dilute fat-free milk to 5 volumes and add sufficient 10 per cent. acetic acid with constant stirring to give 1 per cent. excess over the amount required to precipitate the casein at pH 4·6. After sedimentation, syphon off the liquid and add an equal volume of water. Stir thoroughly, allow to settle and syphon off the liquid, repeating this procedure three times. The precipitate is then dissolved in $\frac{N}{10}$ ammonia and the solution filtered. The precipitation procedure is repeated twice and the casein washed three times with alcohol and then with ether. Finally, the protein is extracted with ether in a Soxhlet apparatus and vacuum dried at 70° C. *See* Casein.

Refs. : Davies ; Richmond ; Rogers.

HANDLING OF MILK. This term is loosely used to describe the various operations by which milk is collected, pasteurised, and distributed to the public. For these the following sections should be consulted :

Production on the farm	Clean milk production ; Cooling ; Dairy farm buildings ; Management of cattle ; Milking machines ; Milk secretion
Collection at depots	Management of country creameries ; Design of dairies ; Mechanical handling ; Cooling ; Platform rejection tests ; National Milk Testing and Advisory Scheme
Transport	Transport ; Costings
Pasteurisation, etc.	Pasteurisation ; Management of pasteurising depots ; Design of dairies ; Mechanical handling ; Instrumentation ; Legal aspects ; Bottle filling and capping ; Bottle washing ; Cleaning of plant ; Detergents
Distribution	Retail, Legal aspects ; Bacteriological grading ; Testing of milk supplies ; Keeping quality ; Costings ; Transport

Refs. : Chalmers ; Enock ; Hammer ; Harvey and Hill ; Rogers ; Williams ; Min. Agric. (1937), " The Handling of Milk and Milk Products ", *Bull.* No. 31, H.M.S.O.

HANNAH DAIRY RESEARCH INSTITUTE. The establishment of the Hannah Institute in 1928 was made possible through the generous gift of the estate of Auchincruive which was presented by the late John M. Hannah, Esq., of Girvan Mains, Ayrshire, for purposes of agricultural education and research. The larger part of the estate was given to the West of Scotland Agricultural College, while the adjoining farm of Kirkhill was reserved for the new research institute. The original buildings were opened in 1931, and some nineteen years later they were very considerably extended, the new extensions being opened in April, 1951 (Fig. Ha 1). The Institute is governed by a Council consisting of eight members; three are appointed by the University of Glasgow, three by the West of Scotland Agricultural College, and two by the Secretary of State. The Principal of the University is chairman. In administering the Institute, the Council is assisted by the Agricultural Research Council of Great Britain and the Department of Agriculture for Scotland.

HANNAH DAIRY RESEARCH INSTITUTE

The main Institute building is situated about 3 miles east of Ayr on the Ayr-Mauchline Road. It contains the administrative offices, a library, several large laboratories, a milk processing room and canteen facilities.

The laboratories are well equipped for research work in Bacteriology, Biochemistry, Histology, Nutrition, Physiology and Technical Chemistry. The processing room contains a model spray-drier, a small milk condensing plant, an homogeniser, canning equipment and other apparatus required for investigating problems involved in the manufacture and storage of milk products. On the farm, in addition to the usual farm buildings, there are calf-houses for studying the nutrition of calves, goat houses in which milk secretion problems can be investigated, a large metabolism house to accommodate nine cows on experiment at one time, and a psychrometric room for studying the effect of climate on the physiology of the bovine.

For purposes of administration and of organising its research work, the Institute is regarded as consisting of seven sections, each of which is discussed briefly below. The staff of each section consists of a Head, graduate assistants, and a number of technical assistants. The Head is responsible to the Director for the work of his section.

The Institute farm of Kirkhill extends to about 135 acres and carries about 100 head of stock.

Grass and Dairy Husbandry. One of the main objects of the work in this section is to develop methods by which high levels of milk production can be maintained with less dependency on feedingstuffs from abroad and without diminishing production of other feedingstuffs in this country. The work involves a study of the influence of nitrogen, phosphorus and potassium and their interactions on grassland production under conditions prevalent in the south-west of Scotland. It also involves a study of the value of different types of pasture for the grazing of dairy cattle, the place of clover in grazing management, the influence of intensity of grassland management on grass and animal production and on subsequent arable crops, the close-folding of dairy cattle and many other allied problems.

Nutrition. The large metabolism house is used to study the metabolism and the nutritive requirements of the lactating cow in more detail and with greater accuracy than has hitherto been possible. It is also used to obtain detailed information on the ability of different feedingstuffs to satisfy these requirements. Other important problems investigated in this section include energy metabolism in the bovine, the efficiency of food utilization in dairy cows and the nutrition of the very young calf.

Biochemistry. The work of this section consists of two main parts. One involves a study of some of the biochemical processes which proceed in the rumen of the cow; the other is concerned with the effect of certain hormones and other factors on the composition of the milk of cows and goats, with particular reference to the content in the milk of some of the minerals, enzymes and vitamins.

Physiology. In view of the lack of fundamental knowledge on the suitability of livestock for export to overseas territories which have tropical or semi-tropical climates, a long-term investigation is in progress on the problem of heat tolerance and the mechanism of temperature control in cattle. A psychrometric room has been designed and equipped for this purpose. A detailed histological study of the skin of cattle of British and tropical breeds is being made, and problems associated with the blood supply to the skin and water transudation through it are also being investigated.

Bacteriology. The work of the Bacteriological Section follows two main lines. The first is concerned with methods by which the bacteriological quality of milk and milk products can be assessed and improved. Under this heading work is done on the cooling of milk at the farm, on the bacterial flora of raw and

FIG. Ha 1 — *Hannah Dairy Research Institute. A view from the South-west*

pasteurised milk and on the keeping quality of milk and milk products. Fundamental studies are also made on the nutritional requirements and metabolic products of certain micro-organisms. The second line of work in this section involves a long-term investigation of some of the micro-organisms of the bovine rumen.

Technical Chemistry. In this section a study is made of the problems associated with the manufacture and keeping quality of dried and evaporated milk products. In addition, the staff of the section are responsible for the chemical analysis required for the work of the Grass and Dairy Husbandry Section. They are also co-operating in work designed to determine to what extent the solids-not-fat content of milk is influenced by heredity.

Veterinary work. In the past the Veterinary Section has done much work on the eradication of bovine tuberculosis and on other bovine diseases such as mastitis, abortion and sterility. The staff of this section continue to co-operate in problems of this type, but at the same time they take an active part in the work of any of the other sections of the Institute in which veterinary collaboration is required.

Further particulars about the Hannah Dairy Research Institute, its work and publications, will be found in the printed report of the Institute which is published every few years. Copies of the latest report can be obtained free of charge by writing to the Secretary of the Hannah Institute, Kirkhill, Ayr.

HARD CHEESE. *See* Cheese, p. 195.

HARDNESS. *See* Cheese, p. 168 ; Rheology.

HAYMAKING. The oldest and still the most important way of preserving summer grass for feeding cattle in winter. However, the importance of haymaking has diminished in recent years because of the introduction of roots such as mangels and swedes, and of imported cattle food and oil cake. The increase in popularity of the silo (p. 958) and of grass drying (p. 494), now in its infancy, will also reduce the farmer's dependence on his hay.

Quality in hay depends on the following factors : (i) The grass should be cut before most of it is in flower, *viz.* June in the south and usually later in the north. (ii) The grass must be dried as quickly as possible, the 85 per cent. moisture being reduced to 15 per cent. If stacked when too green, the hay will get too hot due to microbial action and may even catch fire. (iii) The finest hay can only be made of the good grasses and clovers. The nutritive value is lowered by handling, and also by rain and a too hot sun which cause bleaching and loss of vitamin A.

In the north of England and in Scotland the half dried hay is placed in large heaps known as *pykels* or *cocks*. This precaution reduces the damage done by rain and might well be adopted in the south.

The further growth of meadow grass is called the aftermath and is usually grazed, but in good seasons a second hay crop may be taken. *See* Agriculture ; Feeding ; Grass.

HEALTH OF COWS. The factors favourable to the health of dairy cattle are adequate feeding and water, proper housing (unless out-wintered), sufficient but not too much exercise, moderate climatic conditions.

Disease (p. 407) is best prevented by immediate removal of any infected cattle, adequate hygienic precautions in milking and handling, and regular veterinary inspection.

Ill-health usually results in a decreased yield, but the fat content may be increased. The solids-not-fat is usually decreased, at least in time. *See* Abortion ; Breeding, Feeding and Management of cattle ; Diseases of dairy cattle ; Mastitis.

Refs. : Miller ; Gaiger and Davies ; Min. Agric. (1938), *Bull.* No. 1.

HEAT. A form of energy possessed by a material in respect of the motion of its molecules. The amount of heat in calories required to raise 1 g. of material

1° C., is termed the *specific heat* (in engineering the amount of heat in B.Th.U. to raise 1 lb. 1° F.). The amount of heat to change 1 g. of solid into liquid, or 1 g. liquid into gas is called the *latent heat of liquefaction* (or *evaporation*). *See* Disinfection; Specific heat; Sterilised milk; Steam.

Refs.: Badger and McCabe; Farrall; McAdams (1942), *Heat Transmission*, London; Hutchinson (1952), *Industrial Heat Transfer*.

HEAT DENATURATION OF PROTEINS. Albumin and globulin normally exist in milk in colloidal solution, *i.e.* they will pass through a filter. When this solution is heated above a certain temperature (60° to 65° C.) these proteins become insoluble or coagulated, just as egg-white changes when an egg is boiled. This heat coagulation consists of two reactions—*denaturation* and *agglutination*. The denaturing is a permanent change or irreversible reaction associated with the chemical linkages at the surface of the protein molecule, while the agglutination is a reversible process controlled by such factors as the charge on the particle which is determined by the *p*H and the nature and concentration of the salts in solution. In the presence of salts, as in milk, the rate of denaturation determines the rate of coagulation.

Rowland (1933), *JDR*, **5**, 46, has found that 30 min. heating denatured 10·4 per cent. of the soluble protein at 63° C., 28 per cent. at 70° C., from 52·4 to 67·5 per cent. at 75° C., and 83·4 per cent. at 80° C.

Casein is a heat-stable protein and normal milk requires 12 hr. at 100° C., 1 hr. at 130° C. and 3 min. at 150° C. for complete coagulation. *See* Albumin; Casein; Globulin; Rennet.

Refs.: Richmond; Davies; Rogers.

HEAT, EFFECT ON MILK. From the practical point of view the effect of heat on milk is usually considered from the point of view of (i) pasteurisation—either 145° F. for 30 min. or 161° F. for 15 sec.; (ii) boiling—about 212° F.; (iii) sterilising—about 225° for 30 min.

There are also distinct aspects for consideration: (*a*) physical—state of proteins, calcium salts, etc.; (*b*) chemical—production of sulphydryl compounds, caramelisation of lactose, etc.; (*c*) bacteriological—the destruction of bacteria, especially those affecting the keeping quality of milk, and pathogenic organisms, especially the tubercle bacillus.

(i *a*) PASTEURISATION has only a slight effect on the physical structure of milk, denaturing about 10 per cent. of the albumin + globulin and rendering about 5 per cent. of the calcium insoluble. Cream line is somewhat affected—about 14 per cent. loss by the holder method, and 10 to 20 per cent. loss by H.T.-S.T.

(i *b*) The only significant changes are a slight loss, about 10 per cent. of vitamin B_1 and about 25 per cent. vitamin C.

(i *c*) Both holder and short-time pasteurisation destroy about 99 per cent. of the bacteria in average bulk milk, but this figure can vary considerably. If the milk has a high count of thermoduric bacteria the destruction can be as low as 75 or even 50 per cent. The bacteria surviving pasteurisation—the spore-formers, *Str. faecalis*, the sarcinae and tetracocci, some micrococci and *Microbacterium*—usually do not greatly affect keeping quality.

It can be taken as axiomatic that efficient pasteurisation destroys all pathogens. Thus the tubercle bacillus, the most resistant pathogen commonly found in milk, is destroyed at *c.* 158° F. in the H.T.-S.T. process and phosphatase at *c.* 160° F.

(ii *a*) BOILING denatures all the albumin (see Turbidity test) and renders much of the calcium insoluble. Cream line is destroyed.

(ii *b*) Boiling results in the production of appreciable amounts of sulphydryl compounds (R—SH) from the methionine and cysteine of the proteins (responsible for part of the characteristic smell of hot milk).

(ii *c*) Boiling kills all non-spore-forming bacteria, the vegetative cells of spore-formers and some spores.

(iii *a*) STERILISATION produces the same physical changes in milk as boiling, but to a greater degree.

(iii *b*) In addition to changes in water-soluble proteins and calcium salts, sterilisation produces an appreciable amount of caramelisation due to the formation of humins from the lactose and certain amino acids in the proteins.

(iii *c*) Sterilised milk is quite often sterile in the true bacteriological sense. Sometimes small numbers of heat-resistant spores survive and these may be responsible for taints in the finished product. Spores surviving in milk do not necessarily germinate.

See Browning; Condensed and evaporated milk; Enzymes; Heat resistance of bacteria; Nutritive value; Pasteurisation; Phosphatase; Stability; Sterilised milk; Thermoduric bacteria; Thermophilic bacteria.

Refs.: Richmond; Cuttell; Davies; Rogers; Wilson; Nutrition Reviews in *JDR;* Patton and Flipse (1953), *JDS*, **36**, 766; Patton (1952), *JDS*, **35**, 1053; Zweig and Block (1953), *JDS*, **36**, 427; Ramsdell and Whittier, 437; Ramsdell and Hufnagel (1953), *IDC*, **3**, 1025 (skim milk); Stewart (1951), *JDS*, **34**, 743 (reducing substances); Patton (1950), *JDS*, **33**, 324; Keeney *et al.*, 526; Patton, 904; Patton, *ibid.*, 102.

HEAT RESISTANCE OF BACTERIA. Bacteria, like all living cells, are destroyed by heat if the temperature is sufficiently high and the duration of heating sufficiently long. These factors act inversely—the higher the temperature the shorter the time required to produce a given effect. Bacteria vary markedly in their resistance to heat, the most sensitive being the delicate pathogens like the syphilis organism, and the most resistant being the spores of some species of *Bacillus* which may resist boiling for several hours.

The heat resistance is generally described in terms of the *thermal death point* which means that temperature at which heating for a given time *e.g.* 10 min., kills all the bacteria. This is subject to many conditions including the number of bacteria originally present, so that it is more correct to state that heating to a given temperature for a given time destroys, say, 99 or 99·9 per cent. of the bacteria originally present.

The nature of the medium also plays a great part in the thermal death point, especially the composition and solids content, acidity or *p*H, dissolved gases and oxidation-reduction potential. *See* Condensed and evaporated milk; Disinfection; Heat, effect on milk; Pasteurisation; Stability; Sterilised milk; Thermoduric bacteria; Thermophilic bacteria.

Refs.: Hammer; McCulloch; Rogers; Wilson and Miles; Nichols (1940), *JDR*, **11**, 274 (effect of *p*H and fat).

HEAT STABILITY OF MILK. *See* Alcohol test; Condensed and evaporated milk; Heat, effect on milk; Milk powder; Proteins.

Refs.: Davies; Richmond; Rogers; Whitney *et al.* (1952), *JDS*, **35**, 937 (test).

HEAT TREATMENT OF MILK. This term is a general one covering any of the ordinary commercial heating methods by which the keeping quality of milk is enhanced and pathogenic organisms destroyed. It also includes "shocking" which is a mild treatment, *e.g.* momentarily heating to 150° F., which "shocks" the bacteria and delays proliferation for a short time thus allowing other desired types, *e.g.* starter organisms to become dominant and swamp the miscellaneous types.

Formerly two types of heat treatment were recognised; the official "low temperature" or "holder" pasteurisation involving heating to 145° F. for 30 min., and "flash" pasteurisation or "flashing" which involved heating to some temperature in the region of 75° to 80° C. for an undefined time interval. The latter was very variable and often resulted either in overheated milk with a distinctly "cooked" flavour or in underheated milk which had a poor keeping quality and from which all pathogenic organisms had not been removed. Flash pasteurisation was condemned by most public health authorities and is to-day virtually extinct in this country, being superseded by high-temperature short-time pasteurisation. *See* Butter; Cheese; " Flashing "; Pasteurisation; " Shocking "; Sterilised milk ; Uperisation ; Vacreation.

Refs.: Cuttell ; Enock ; Harvey and Hill ; Hill ; Wilson.

HEAT TREATMENT AT COLLECTING DEPOTS. Normally the milk consumed in the densely populated areas is collected at country depots, cooled to 38° to 40° F. and sent in tankers to pasteurising depots in or near big towns. In cold or moderate weather, no difficulty is experienced in securing a milk of good hygienic quality which gives a satisfactory pasteurised product. In hot weather, however, and especially in heat-waves (*e.g.* maximum atmospheric shade temperatures over 80° F.) milk may easily arrive at the pasteurising depot with a very high bacterial count, *e.g.* 10 to 50 million colonies per ml., with the result that either it is rejected by the buyer or, if accepted, gives a poor quality pasteurised milk. There has lately been a tendency for tanker milk travelling long distances to be heat-treated at the collecting depots before dispatch. As the result of this treatment, the milk arrives in good condition from the point of view of the quick tests that are usually made and so is accepted without question. As an example of the effect of heat treatment on such milk, typical figures are quoted in Table He I.

TABLE He I

	Resazurin disc no.		*Methylene blue*	*Titratable acidity* (%)
	10 *min.*	1 *hr.*		
Before dispatch (raw) . . .	4	0	40 min.	0·15
On receipt (raw) . . .	2	0	15 min.	0·165
On receipt (heat treated) . .	6	5½	4½ hr.	0·15

Nevertheless, those experienced in the processing of milk are not quite happy in accepting such milk because of the effect of double heat treatment on the milk and on the plant, apart from the legal aspects. Naturally there is very little experimental evidence available, and on balance the pasteurising depot is probably better off with heat-treated milk of apparently good bacteriological quality than with raw milk of very bad bacteriological quality. The objections to the use of milk that has already received a heat treatment are (i) the uncertainty of behaviour of the twice-heated milk ; (ii) the fact that, for a given standard on bacteriological tests, heated milk may give a product of poorer keeping quality than would raw milk ; (iii) the double heating results in a poorer cream line ; (iv) it may lead to a " build-up " of thermoduric organisms in the plant (pasteurising equipment, pipe lines, tanks, bottle-washing machines, and bottles).

HEATED MILK, TESTS FOR. The detection of heated milk was formerly one of the more important tests in dairy scientific work, but it is highly significant that such tests are now rarely used. This is because heated milk is now the rule rather than the exception, at any rate, in the more thickly populated areas, and all other tests have now been rendered virtually obsolete by the phosphatase test (p. 834) which is used to detect under-heated milk or small amounts of raw milk in heated milk.

The classical tests, which depended on the destruction of enzymes, changes in the physical condition of certain constituents, and chemical changes in certain constituents are tabulated below (Table He II).

TABLE He II

SUMMARY OF TESTS FOR HEATED MILK

Test	Temperature range
Enzymes	
Catalase	90° to 95° C.
Peroxidase	70° to 80° C.
Schardinger's	70° to 80° C.
Phosphatase	60° to 75° C.
Physical changes	
" Precipitation " of albumin	60° to 80° C.
Rate of rise of cream	60° to 70° C.
Chemical changes	
Production of sulphydryl substances	75° to 85° C.

See Enzymes; Pasteurisation; Phosphatase test; Sterilised milk; Turbidity test.

Refs. : Chalmers ; Hammer ; Orla-Jensen ; Rogers.

HEHNER AND RICHMOND'S FORMULA. An early formula for relating sp. gr. with fat and total solids : $T = 0{\cdot}254\,G + 1{\cdot}164\,F$.

HERD REPLACEMENT. *See* Management of dairy cattle.

HEXADECENOIC ACID. *See* Fatty acids.

HEXAMETAPHOSPHATE. *See* Calgon; Detergents; Water.

" HIPED." A cow horned by another.

HIPPOPOTAMUS MILK. *See* Mammals.

HISTORY OF DAIRYING. *See* Legal aspects ; Milk marketing.

Refs. : Pirtle (1926). *History of the Dairy Industry*, Chicago ; Cronshaw ; Enock ; Orla-Jensen ; Richmond ; Walworth ; Capstick (1950), *JSDT*, **3**, 151.

HIPPURIC ACID. *Ref.*: Patton (1953), *JDS*, **36**, 943.

HOFIUS-RICHTER PROCESS. This method for preserving milk depends on the lethal action of oxygen under pressure at low temperatures. It has been developed in Germany and elsewhere on the Continent, but has not received serious attention in this country.

Refs.: Pette (1953), *D*, **70**, 327; de Vleeschauwer and Hendrickx (1946), *Med. Landb. Opzoek. Gent.*, **11**, 262. Rodenkirchen (1937), *Milchw. Forsch.*, **18**, 255; Mattick (1936), *J. Min. Agric.*, **43**, 516.

HOLLAND.

Refs.: Boekel (1953), *JSDT*, **6**, 202; Various (1953), *NMDJ*, **7** (Spec. No.); Frens (1953), *DSA*, **15**, 437; Mulder *et al.*, 445; van de Wiel (1949), *IDC*, **4**, 577; *L'Agriculture aux Pays-bas* (1937), The Hague.

HOLDER. *See* Pasteurisation.

HOLES IN CHEESE. *See* Cheese, p. 168 ; Propionic acid fermentation.

HOLSTEIN. Another name for Friesian.

HOMOGENISATION. Any shearing force exerted on the fat globules in milk will tend to homogenise the milk. Although, strictly speaking, the term means to make uniform, the essential characteristic of homogenised milk is that the fat globules are much smaller. In ordinary milk the globules vary in diameter from about 1 to about 18μ, average about 4μ, and after homogenisation the globules are from about 2 to about 1μ in diameter, according to the pressure of homogenisation. Homogenised milk is more viscous, creamier (" smoother ") and is more digestible, as it gives a weaker curd, is more liable to rancidity and oxidation of the fat, and gives no " cream line ". The last property is the most important in liquid milk, and arises because the viscosity of the serum and inter-surface forces are sufficient to keep the small fat globules evenly distributed (*see*

Fat globules ; Stokes's law). During homogenisation the protein-lipoid film is ruptured, but these surface active substances are re-adsorbed afterwards on the surface of the smaller globules. Nevertheless, the adsorbed film now has different properties as homogenised cream does not whip so well as ordinary cream, although homogenised ice-cream mix may whip better.

Fig. Ho 1 illustrates the fat globules in milk before and after homogenisation.

Homogenisers. Typical homogenisers are shown in Figs. Ho 2 and 3, and the valve components in Figs. Ho 4 and 5. Milk is forced by a number (usually 3) of reciprocating piston type pumps through the homogenising valve at pressures up to 3000 lb. p.s.i. Although different types of valve are used, they are all essentially the same " lift and drop " in action, and a very strong spring returns the valve to its seat. Both valve and seat must be of very hard and durable materials, as must also be the breaker ring which takes the force of the milk. The valve lifts only a few thousandths of an inch and the milk is forced through the fine annular space at high velocity. The pumps must work efficiently, and the suction and discharge valves open easily and close tightly. The milk usually passes through a strainer or filter, and a safety valve and pressure gauge are always incorporated.

Other types of homogenisers have been tried, especially rotary, high-speed agitators and ultra-sonic vibrators. The second is not very efficient for milk, and the third very expensive.

Factors affecting Homogenisation. (1) ***Pressure.*** The following results were obtained by Tracy.

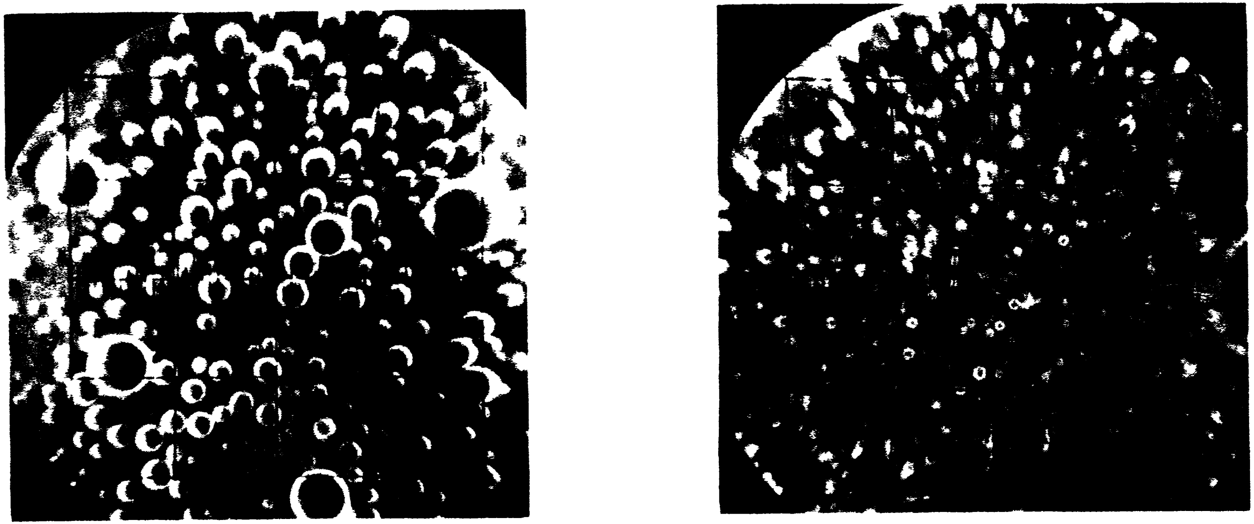
TABLE Ho 1

Pressure lb. p.s.i.	*Range of size of globules* μ	*Average diameter of globules* μ
None	1 to 18	3·71
500	1 to 14	2·39
1000	1 to 7	1·68
1500	1 to 4	1·40
2000	1 to 3	1·08
2500	1 to 3	0·99
3000	0·5 to 2	0·76

Increasing pressures result in increased tendency to " clump ", *i.e.* the small globules cling together. This is a disadvantage as it affects viscosity, and, in ice cream, whipping power and " over-run ". Clumps can be broken up by homogenising a second time at a low pressure, *e.g.* 500 lb. p.s.i.

TABLE Ho 2 (Rahn (1925), *MF*, **2**, 382)

Diameter of globules (μ)	*Percentage globules*		
	20° C.	40° C.	65° C.
0 to 1	2	2	4
1 to 2	29	37	75
2 to 3	23	21	9
3 to 4	30	25	12
4 to 5	16	15	0
5 to 6	0	0	0



(*a*) *Unhomogenised Milk.* (*b*) *Homogenised Milk.*

FIG. Ho 1.

[*By courtesy of Creamery Package Ltd.*

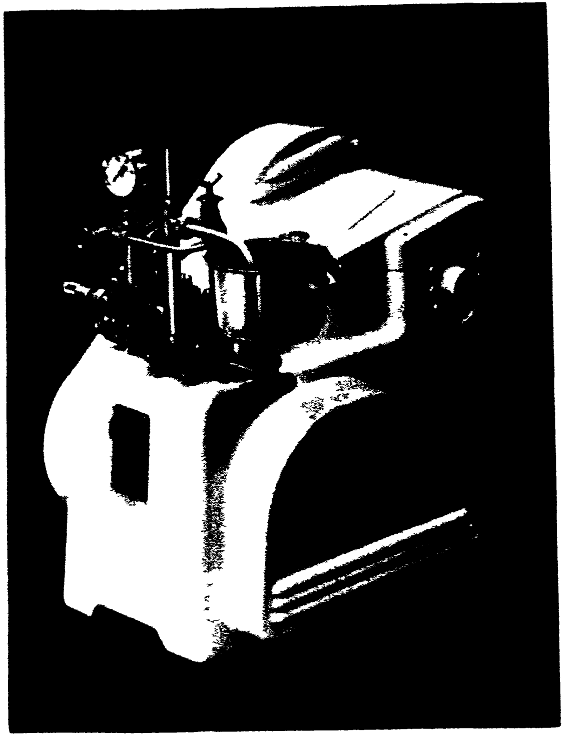


FIG. Ho 2.—*The Rannie totally enclosed Homogeniser with Automatically Ventilated Motor Chamber. The Special Head Produces a Whirling Effect in the Liquid.*

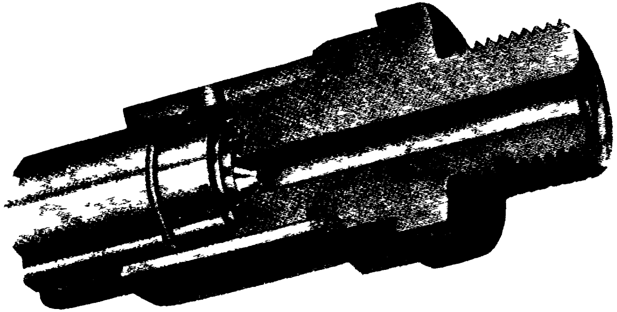
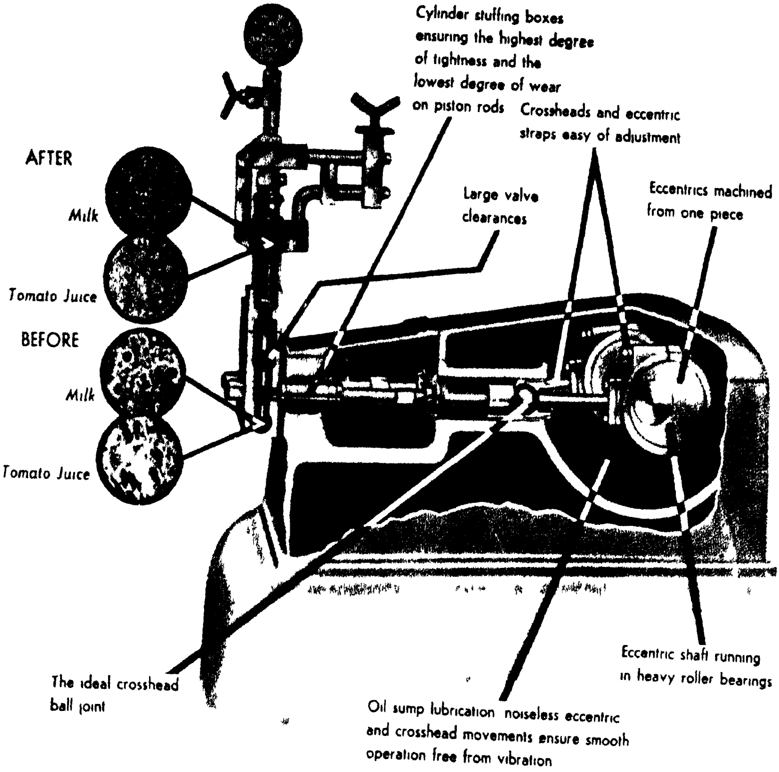


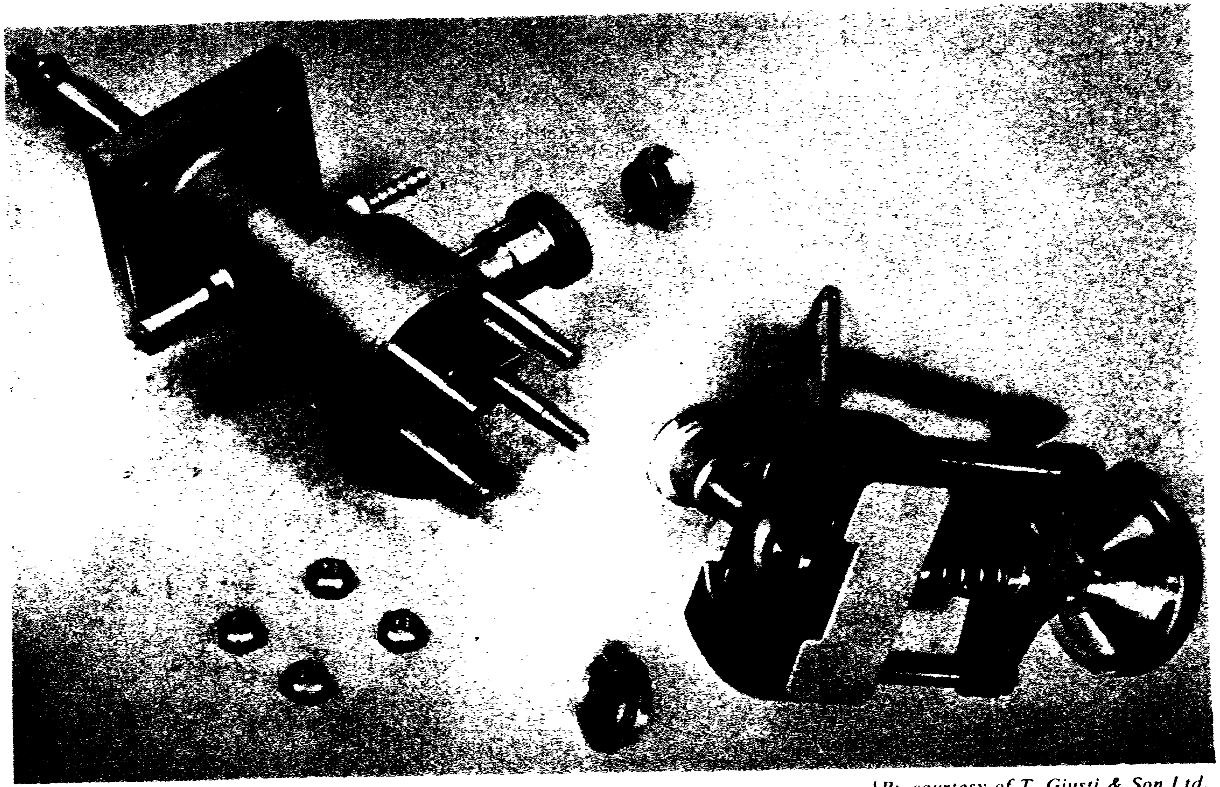
FIG. Ho 4.—*The Original Rannie "LW" Homogenising Head.*

[*Photos by courtesy of Hiron & Rempler Ltd.*


Cylinder stuffing boxes ensuring the highest degree of tightness and the lowest degree of wear on piston rods
Crossheads and eccentric straps easy of adjustment
AFTER
Milk
Tomato Juice
BEFORE
Milk
Tomato Juice
Large valve clearances
Eccentrics machined from one piece
The ideal crosshead ball joint
Eccentric shaft running in heavy roller bearings
Oil sump lubrication noiseless eccentric and crosshead movements ensure smooth operation free from vibration

[*By courtesy of Hiron & Rempler Ltd*

FIG. HO 3 - *Section through the Rannie Homogeniser. Capacity* 110 *gal. per hr.*



[*By courtesy of T. Giusti & Son Ltd.*

FIG. Ho 5.—*Homogeniser Head Dismantled.*

(2) ***Effect of temperature.*** Temperature considerably affects clumping. This is considerable at 110°-120° F., but much less at 145° F.

Higher temperatures also increase the efficiency of homogenisation (Table Ho 2).

(3) ***Effect of chemical substances.*** Calcium salts and acidity promote clumping; sodium citrate and phosphate reduce it.

Use of Homogenising in the Dairy Industry. (1) Milk is homogenised to give a product which remains of uniform composition (no rising of cream) for at least a week. Homogenised milk is valued by restaurants for this reason, and it is also more creamy in tea and coffee. It is claimed to be more palatable, and is certainly more digestible, partly because of the smaller fat globules and partly because of the lower curd tension (*q.v.*).

(2) Sterilised milk (*q.v.*) is always homogenised to prevent the formation of the unsightly cream plug.

(3) Evaporated milk (p. 277) is also always homogenised to prevent the fat rising.

(4) Single cream (18 per cent.) is usually homogenised to increase viscosity (thickness), and to prevent churning or " oiling off ". It does not whip well, however, and is heat-sensitive, and therefore sometimes gives " feathering " in coffee.

(5) Some cheese, especially soft cheese, are made from homogenised milk. This gives a creamier and more velvety body to the cheese.

(6) Ice cream mix (*q.v.*) is greatly improved as homogenising improves body and texture, facilitates whipping and so assists the obtaining of a good " overrun ", permits the use of a wider range of fats and other mix constituents and prevents separation of fat in the freezer.

See Cream line; Fat globules; Ice cream; Sterilised milk.

Refs.: Witting (1953), *IDC*, **2**, 386; Ashworth (1951), *JDS*, **34**, 317 (turbidity as index); Loo *et al.* (1950), *JDS*, **33**, 692 (cavitation as a factor); Wittig (1949), *IDC*, **3**, 118; Spur (1949), *IDC*, **5**, 94 (digestibility); Schmidt (1951), *M*, **6**, 424 (dispersion measurement); Schulz, W., 429.

HORMONES. A *hormone* is a specific chemical substance, produced by an endocrine gland, which circulates in the blood to all parts of the body and which, in small amounts, influences the rate at which cellular functions proceed in other organs without itself contributing significant quantities of matter or energy.

The activity of the endocrine glands are complexly inter-related and their hormones play an important part in correlating and integrating the functions of the organism as a whole and in maintaining the internal environment in its normal condition of stability and constancy. The anterior-pituitary gland is of major importance in this process on account of its wide influence on other endocrine glands.

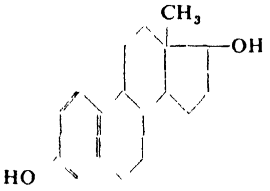
Pituitary Hormones. The pituitary gland, situated at the base of the brain in the hypophyseal fossa of the sphenoid bone, is functionally the most complex of all the endocrine glands. This gland is readily divisible into *anterior* and *posterior* parts or lobes. Some of the hormones secreted by the anterior lobe are concerned with the regulation of the function of other endocrine glands and are designated accordingly—*gonadotrophin*, *adrenotrophin*, *thyrotrophin*. These influence the functioning of the gonads, the adrenal cortex, and the thyroid, respectively. There are, in fact, two gonadotrophic factors secreted by the anterior pituitary, (*a*) follicle-stimulating hormone (F.S.H.) and (*b*) luteinising hormone (L.H.). In addition, the anterior pituitary secretes a *lactogenic* hormone (also termed *prolactin*, *galactin*, *mammotropin*, or *luteotrophin* (?)), and a *growth factor* (*diabetogenic factor*). Other hormones, *e.g. mammogens*, have been described as being elaborated by the anterior pituitary but their reality is still in doubt.

The posterior lobe produces two hormones, one a *pressor* factor which raises blood pressure and the other an *oxytocic* factor (*oxytocin* or *pitocin*) which causes smooth muscle to contract, especially the smooth muscle of the uterus, intestine, and bladder.

The hormones of the pituitary are proteins. Some have been isolated in a pure state.

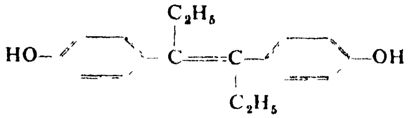
Gonadal or Sex Hormones. Of prime importance in the reproductive processes are the hormones secreted by the ovaries of the female and by the testes of the male. The gonadal hormones are steroids, their molecule possessing the cyclo-pentano-perhydro-phenanthrene ring system. There are three types of gonadal hormones: (1) *Oestrogens*, (2) *Progestogens*, and (3) *Androgens*.

Oestrogens are hormones responsible for the changes in the vagina and uterus characteristic of oestrus or " heat ", the female secondary sexual characters, and oestrous behaviour in non-pregnant animals. The main source of oestrogen in the non-pregnant animal is the ovary where it is present as *oestradiol*. The follicle is generally considered as being responsible, but the exact site of secretion is uncertain. Oestrogens may also be secreted by the cortex of the adrenal glands, by the testes and, in pregnant females, probably by the placenta.



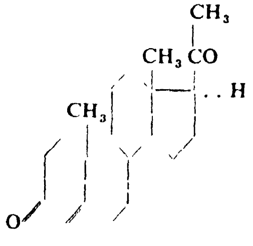
Oestradiol

" **Synthetic Oestrogens** " are substances which for all practical purposes have the same physiological properties as the natural oestrogens but which can be readily and cheaply synthesised in the laboratory. These compounds are not steroids, but are generally stilbene derivatives, the most common being *stilboestrol*, *hexoestrol*, and *dienoestrol*.



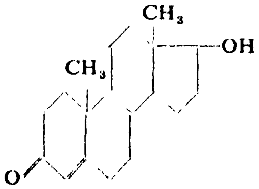
Stilboestrol

Progestogens are substances responsible for preparing the endometrium or lining of the uterus for the reception of the fertilised ovum. The most important progestogen is *progesterone* elaborated by the corpus luteum or " yellow body " of the ovary. It is highly probable that the adrenal cortex and the placenta may also secrete this hormone.



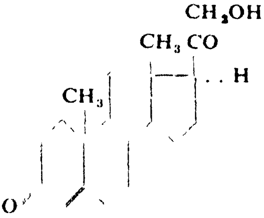
Progesterone

Androgens are hormones responsible for the development and function of the male accessory reproductive organs, and secondary sexual characters. The principal androgen produced by the testes is *testosterone.* Androgens may also be secreted by the ovary and the adrenal cortex.

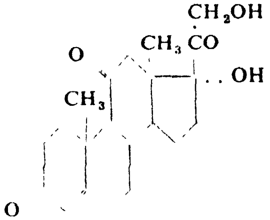


Testosterone

Adrenal Hormones. The adrenal or supra-renal glands are two small glands situated close to the kidneys. Each is made up of an outer zone or *cortex* and an inner zone or *medulla.* The cortex secretes steroid hormones of which, some control the electrolyte balance and water metabolism of the body (*e.g.* deoxycorticosterone), while others (*e.g.* 17-hydroxy-11-dehydrocorticosterone) influence the intermediary metabolism of proteins and carbohydrates.

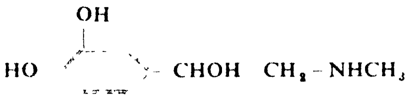


Deoxycorticosterone



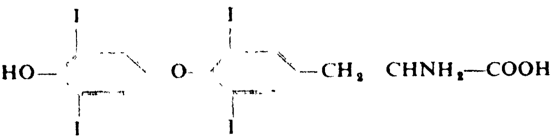
17-hydroxy-11-dehydrocorticosterone
(Cortisone)

The medulla secretes *adrenaline* which has a profound influence on the circulatory system and affects carbohydrate metabolism. The removal of the adrenal medulla, however, results in no serious deficiencies in the mammal, and adrenaline is probably of main value to the animal in emergencies. Chemically, adrenaline is dihydroxy-phenyl-ethanol-methylamine.



Adrenaline

Thyroid Hormone. The thyroid gland consists of two lobes on either side of the trachea near its junction with the larynx. In most animals the two lobes are connected. The thyroid gland secretes a hormone—*thyroxine*—which is an iodo derivative of hydroxy-phenyl-tyrosine. This hormone exerts a controlling influence over metabolism in general.



Thyroxine

Pancreatic Hormone. The pancreas is both an exocrine and endocrine gland. In addition to the pancreatic digestive juice which it pours into the intestine through the pancreatic duct, there are, throughout its substance, collections of cells (*the cell islets of Langerhans*) which pass their secretion into the blood stream. This secretion, *insulin*, plays an essential role in the utilisation of carbohydrates in the body. A deficiency of insulin leads to diabetes. Insulin is a protein and has been prepared in a pure form.

Parathyroid Hormone. The parathyroid glands are small glands situated near to, or in some species embedded in, the thyroid glands. These glands secrete a hormone—parathyroid hormone—which plays an essential role in the metabolism of calcium. This hormone appears to be a protein.

For further information on hormones, consult Cameron (1947), *Recent Advances in Endocrinology*, London, and Robson (1947), *Recent Advances in Sex and Reproductive Physiology*, London.

Hormones in Dairy Husbandry. It is only within the last few years that the application of hormones to problems of dairy husbandry has become possible since for this purpose the hormones in question must be readily available, their physiological actions well established, and their cost sufficiently low to render their use economic.

Hormone preparations now available are highly purified and of great biological activity. In preliminary field trials certain hormone therapies have given very promising results, but it is well to remember that these hormonal treatments are not yet perfected and must be used *with discretion* if undesirable sequelae are to be avoided.

Anterior-pituitary Hormones. Extensive experiments by Folley and Young in this country and Azimov in Russia have shown that crude extracts of ox anterior pituitary can be used to increase by at least 20 per cent. the milk yield of cows in *declining* lactation. The extract requires to be injected every second day in amounts equivalent to 2·5 g. of fresh tissue. The response soon falls off when the injections are stopped. This treatment has no detrimental effects on the animal's health. The necessity for frequent injections and the restricted supplies of the extract are limiting factors in the wide scale application of this treatment. (For further information, *see* review by Young (1947), *Brit. Med. Bull.*, 5, No. 2-3, 155.)

Oestrogenic Hormones. The artificial induction of lactation in barren heifers and cows has been successfully achieved by the use of synthetic oestrogens. (The natural oestrogens are too costly to use in farm practice.) The oestrogens may be given by repeated injections of oily solutions or by the implantation, under local anaesthesia, of compressed tablets of oestrogen under the skin. The administration of oestrogens by mouth has not given very satisfactory results. At present, the tablet-implantation technique appears to be the method of choice. The synthetic oestrogens are relatively insoluble in the body fluids, so the total weight of oestrogen implanted must be 2 to 5 g. to ensure a sufficient level of oestrogen in the blood to produce mammary development and milk secretion. It is desirable to use large tablets for implanting (1 g. tablets are best but are difficult to manufacture in large quantities). Secretion can be drawn from the udder 2 to 3 weeks after the beginning of the treatment. At first the secretion is colostrum-like but with daily milking the quantity rapidly increases and by the time the daily yield reaches ½ gal. (2¼ litres) the composition of the milk is in every way normal. When the daily milk yield reaches a peak, the oestrogen injections are stopped or the unabsorbed portions of the tablets are removed. In most cases the daily yield will then show a further increase. In successful cases lactation will continue for a normal lactation period. The hormone content of the milk from these animals is not appreciably higher than that of normal milk.

At present, this treatment has certain drawbacks. Only about 50 per cent. of animals treated will respond satisfactorily, *i.e.* will give at least 1½ gal. (6¾ litres) per day. Further, during the period of oestrogen treatment, the animals are in a state of continual oestrus which may amount to nymphomania and, unless they are kept in individual isolation, their behaviour may result in injuries such as fracture of the hip bones. This therapy is therefore mainly suitable for selected cases of infertility in cows and heifers of good milking potentialities whereby they may be saved from untimely slaughter, and further treatment for infertility may be carried out while the animals are producing economic yields of milk. (For further information, *see* review by Malpress (1947), *Brit. Med. Bull.*, **5**, No. 2-3, 161.)

Iodo-proteins. While the galactopoietic properties of thyroxine have been recognised for some years, the practical application of this knowledge was greatly limited by the necessity of giving frequent injections, since thyroxine does not exert its full action when given by mouth and dried thyroid gland which is effective by mouth was relatively expensive. By combining iodine with certain proteins, such as casein, it is now possible to produce, on a large scale and relatively cheaply, *iodo-proteins* which have the same physiological effects as dried thyroid gland when given by mouth. It has now been well established that by feeding *carefully regulated* doses of iodo-proteins to cows in declining lactation, marked increases in milk and butterfat yields will follow. The milk obtained from cows treated with iodo-protein is normal in composition and there is no evidence that thyroxine-like substances are excreted in it.

It is essential that iodo-proteins be used with discretion since over-dosage will result in over-stimulation of the general body metabolism resulting in a fall in milk yield and a marked loss of body weight with probable impairment of the animal's health. Further trials are at present being carried out by the Ministry of Agriculture to study the long term effects of this treatment on the animal's health. If these experiments prove satisfactory iodo-proteins will find an extensive use in dairy husbandry. (For further information *see* review by Young (1947), *Brit. Med. Bull.*, **5**, No. 2-3, 155.)

Recently a new synthetic process for the preparation of thyroxine has been developed in this country which has made possible the production at low cost of relatively large quantities of pure thyroxine. Contrary to earlier beliefs, thyroxine has now been shown to be fully active when fed by mouth and synthetic thyroxine is now completely replacing iodo-proteins for use in dairy husbandry. Thyroxine being a pure substance, no tedious methods of biological assay are necessary and very much smaller doses are required (*see* Bailey, Bartlett and Folley, *Nature*, Lond., **163**, 800 (1949).

Gonadotrophic Hormones. In addition to the use of the above-mentioned hormone therapies in dairy husbandry, there has been in recent years considerable interest in the possibility of using hormones for stimulating the inactive ovaries of goats during the anoestrous season so that they may be bred. This would be of considerable value to goat keepers, for if goats could be mated " out of season " (*i.e.* during anoestrus) to kid down in the autumn, an adequate supply of milk during the winter months would be ensured.

The hormone used for this purpose is a gonadotrophic hormone prepared from the blood serum of mares during certain stages of pregnancy; it is usually termed " pregnant mares' serum gonadotrophin " or simply " P.M.S." (This is not a pituitary hormone but is secreted by certain portions of the endometrium or lining of the uterus of the mare.) A single injection of P.M.S. (800 to 1000 international units) is generally sufficient to evoke oestrus and normal ovulation in the anoestrous goat. Considerable success has been achieved in field experiments with this treatment although further research is desirable. (For further information *see* review by Greenbaum (1947), *J. Endocrinol.*, **5**, No. 3, xxviii.)

HORSE-POWER. A rate of working to produce 33,000 ft. lb. per min., equal to 745·2 watts when $g = 980$.

HORTVET APPARATUS. The standard apparatus for determining the freezing-point of milk (p. 485). The cooling of the milk is produced by the evaporation of ether or by a refrigeration unit. The ether method is the most suitable when a small number or occasional samples are tested. For continuous testing the Temple apparatus is recommended.

Ref.: Richmond; *Milk Testing.*

HOT IRON TEST. *See* Cheese, p. 168.

HOTIS TEST. A simple test for the presence of mastitis streptococci. It is made by adding bromcresol purple to samples of milk direct from the udder and incubating at 37° C. (Hotis (1936) U.S. Dept. Agric. Circ. No. 400; McCulloch and Fuller (1939), *JB*, **38**, 447; Mattick *et al.* (1941), *JDR*, **12**, 139; Stirling and Watts (1943), *SAB*, 67). The growth of lactose fermenting organisms is then shown by a change in colour of the indicator.

For a critical discussion of the test and description of a modification see McLeod and Watts (1945), *SAB*, 37. *See* Abnormal milk; Mastitis; Media.

HOT WEATHER PROBLEMS. The dairy industry has an easy period from November to March and a very strenuous time from May to July, when the peak of production often coincides with the hottest weather. During this period the staff are engaged long hours and extra staff are frequently taken on, especially in manufacturing creameries which may be on only a maintenance basis in winter. Some manufacturing depots handle liquid milk only in winter. The chief problems in hot weather are: (i) handling the peak production and getting the milk in and away as soon as possible ; (ii) ensuring efficient platform checking ; (iii) cooling the warm milk to 38° F. ; (iv) organising the creamery routine for manufacture ; (v) controlling the quality of the manufactured product under adverse conditions. *See* Clean milk production ; Cooling ; Management of creameries, of pasteurising depots ; Refrigeration.

HUMAN MILK. Human milk differs in several ways from cow's milk. It is more alkaline and contains less casein and more albumin, and for this reason will not form a firm clot with rennet as cow's milk does. This is fundamentally the reason why infants digest cow's milk less easily than human milk. Milk from women varies much more widely in composition than that of the cow, presumably because the present dairy cow has been bred for milk production and is maintained under regular conditions. Moreover, " cow's milk " is usually the mixed milk of at least a few cows while " human milk " is normally the milk of a single woman. Analytical data are given in Table Hu I.

HUMANISED MILK. In order to make cow's milk resemble human milk in its behaviour in the digestive tract of infants, various procedures have been suggested. The most important change to secure is a reduction in the relative amount of casein and calcium and/or in the ability of the milk to form a hard clot in the stomach.

The following methods may be used :

Simple method. (i) Allow 1 pint of fresh raw milk to stand overnight in the refrigerator or a cool place. The next morning pour off the top half, dilute this upper half with water to make up 1 pint again and add 1 oz. cane sugar.

(ii) *More elaborate.* As (i) above but add ½ teaspoonful of sodium bicarbonate ($NaHCO_3$) and 1 oz. of lactose instead of ordinary sugar.

(iii) A product very near to human milk in composition can be obtained by proceeding as above but adding the calculated amount of whey paste or whey powder to the milk and neutralising to pH 7·2.

See Infant foods.

Refs.: Al and Wiechers (1952), *R*, **5**, 256.

TABLE Hu I

Composition of Human and Bovine Milk

	Approx. % content (average)	
	Human	*Bovine*
Fat	3·6	3·75
Protein	1·2	3·4
Casein	0·8	3·0
Albumin and globulin	0·4	0·4
Lactose	6·5	4·8
Salts	0·2	0·7
Calcium	0·036	0·12
Sodium	0·02	0·04
Potassium	0·05	0·14
Phosphorus	0·018	0·095
Chloride	0·04	0·08
Citric acid	0·1	0 2
Trace elements		
Iron	0 12 mg.	0 08 mg.
Copper	0 06 mg.	0 016 mg.
Manganese		5 γ
Iodine	4·5 γ	5 γ
Vitamins		
A	200 to 500 I.U.	28 to 280 I.U.
B_1	1 to 4 I.U.	15 to 25 I.U.
B_2 Riboflavin	0·04	0 1 to 0·3 mg.
B_2 Nicotinic acid	0·18	0·085
C	4 mg.	2 mg.
D	0 4 to 10	0·3 to 5·0 I.U.

See Infant foods; Mammals, Nutritive value.

Refs Kon and Mawson, Morrison (1952), *Human milk*, Tech. Com. 18, Com. Bur. Anim. Nutr.; Wilson; Platt and Moncrieff (1947), *Brit Med. Bull.*, **5**, 177.

HUMIDITY. Humidity is usually expressed as the *relative humidity* of the atmosphere. Air can " take up " a certain amount of water as water vapour or gas and the higher the temperature the greater the amount and the greater the vapour pressure of water. In dairying, humidity is of most concern in relation to mould growth in butter (p. 149), and the relative humidity of the atmosphere is of more importance than the water content of the material. A high humidity is also necessary for the " blueing " or mould growth in Stilton, Roquefort, and Gorgonzola cheese (p. 168) hence the ripening of such cheese in cellars and caves which naturally have a high humidity. Moulds do not usually grow if the relative humidity is below 70 per cent. The normal humidity in England is 80 to 90 per cent., varying from about 50 to 95 per cent. The maximum relative humidity is by definition 100 per cent. and when this is reached, condensation of water takes place and evaporation ceases.

Refs.: Griffiths ; *DSIR* (1933), " The Measurement of Humidity in Closed Spaces", H.M.S.O.

HYDROGEN ION CONCENTRATION. The acidity of all solutions is due to the *hydrogen ions* formed from the acidic substances present, thus

$$\underset{\text{hydrochloric acid}}{HCl} \rightarrow \underset{\text{hydrogen ion}}{H^+} + \underset{\text{chloride ion}}{Cl'}$$

The more hydrogen ions present, the more acid the solution. If 1 g. hydrogen ions is present in 1 l., the solution is *normal* (N) in respect of hydrogen ions.

As generally only small quantities are present, the negative logarithm of the concentration of hydrogen ions in g. per l. is used as a convenient shorthand code and termed the *p*H. The *p*H and actual concentration of hydrogen ions in various solutions are shown in Table Hy I.

TABLE Hy I

Substance	*Acidity*	*Concentration of hydrogen ions g. per l. (approx.)*	*p*H *(approx.)*
$\frac{N}{10}$ hydrochloric acid	Very strong	0·1	1
$\frac{N}{100}$ hydrochloric acid	Very strong	0·01	2
$\frac{N}{10}$ acetic acid	Strong	0·001	3
Final acidity of *Str. lactis* in milk	Very sour	0·0001	4
Milk clotting by souring at 18° C.	Sour	0·00001	5
Milk clotting on boiling	Slightly soured	0·000001	6
Distilled water	Neutral	0·0000001	7
Hard water	Slightly alkaline	0·00000001	8
Sodium bicarbonate solution	Fairly alkaline	0·000000001	9
Weak detergent	Alkaline	0·0000000001	10
1 per cent. soda ash	Alkaline	0·00000000001	11
$\frac{N}{100}$ caustic soda	Strongly alkaline	0·000000000001	12
$\frac{N}{10}$ caustic soda	Strongly alkaline	0·0000000000001	13

In industrial practice, hydrogen ion concentration or *p*H is measured with a *p*H meter using a glass electrode (Fig. Hy 1). The instrument is standardised with a buffer solution of known *p*H, usually potassium hydrogen phthalate at *p*H 3·99. *See* Acidity ; Detergents ; Media, p. 674 ; Quinhydrone electrode.

Refs.: Richmond; Rogers, B.S. 1647 (1950) (*p*H scale). Davis (1950), *I*, **19**, 44, 84, 146 (review); Reeder (1950), *M*, **5**, 391, 426, (1951), **6**, 54, 91, 165 (*p*H and salts); Hills (1947), *JDR*, **15**, 62 (effect of NaCl); Dole, 1941, *The Glass Electrode*, London; "Symposium on *p*H Measurement" (1946), *Amer. Soc. Test Materials*, Phil., Pa., U.S.A.; Britton, Clark.

HYDROGEN PEROXIDE. The strength of H_2O_2 solutions is usually expressed in *volumes* which is a measure of the *volume* of molecular oxygen which is obtainable by complete decomposition

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

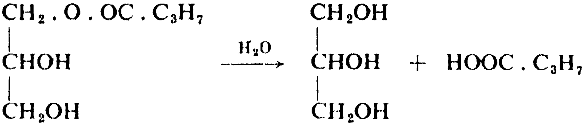
Hydrogen peroxide is one of the classical preservatives for milk (*see* Budde, p. 83) and may be detected by a number of colour reactions, *e.g.* starch + potassium iodide (blue), titanium sulphate (orange), orthomethyl phenol sulphate or ortol (red), sodium orthovanadate in acid (red) (Werther's test).

Hydrogen peroxide is a powerful oxidising agent and yields active oxygen in the presence of peroxidase (p. 833) and traces of copper. Oxidation of this character in milk may produce oiliness, cardboard flavour, etc. Catalase, present in leucocytes and most bacteria, decomposes H_2O_2 to give molecular or ordinary oxygen. *See* Auto-oxidation ; Catalase.

HYDROGENATED OILS. Fats containing large proportions of unsaturated fatty acids (p. 464) are soft or exist as oils, *e.g.* cotton seed oil, ground nut oil and whale oil. By catalytic hydrogenation with hydrogen in the presence of catalysts such as finely divided nickel, the soft fat or oil becomes hardened to yield a fat which can be used for margarine or as a substitute for butter. *See* Butter; Fat; Margarine.

Ref.: Jamieson (1943), *Vegetable Fats and Oils*, N.Y.

HYDROLYSIS. In a general sense this term means the splitting of a compound and the addition of water to the components:



$$\begin{array}{l} CH_2.O.OC.C_3H_7 \\ | \\ CHOH \\ | \\ CH_2OH \end{array} \xrightarrow{H_2O} \begin{array}{l} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \end{array} + HOOC.C_3H_7$$

glyceryl butyrate (monobutyrin) glycerol butyric acid

$$\underset{\text{trisodium phosphate}}{Na_3PO_4} \xrightarrow{H_2O} \underset{\text{disodium hydrogen phosphate}}{Na_2HPO_4} + \underset{\text{sodium hydroxide}}{NaOH}$$

$$\underset{\text{lactose}}{C_{12}H_{22}O_{11}} \xrightarrow{H_2O} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{galactose}}{C_6H_{12}O_6}$$

Hydrolysis may proceed automatically on dissolving a substance in water or be accelerated by (i) heat; (ii) acids; (iii) alkalis; (iv) enzymes, *e.g.* lipases.

HYDROMETERS. The usual form of hydrometer is a glass bulb half filled with lead shot and surmounted by a stem containing a scale, the level of liquid indicating the density of the liquid in which the hydrometer is floating. For testing the density of milk for S.N.F. determinations, a special type called a *lactometer* (p. 600) is used (*see* Solids-not-fat). Hydrometers are also used for testing the strength of many liquids such as brine (p. 128). *See* Density; Lactometer; Solids-not-fat; Total solids.

HYGIENIC PRECAUTIONS IN DAIRIES. Although modern methods and equipment have reduced the chances of infection in milk handling and processing to very small proportions, the following aspects should always receive the attention of the manager:

(i) the Milk and Dairies Regulations (1949) should be observed in all details;

(ii) any member of staff having any symptom of ill-health should report immediately to the manager, who should always observe precautions and take medical advice at his discretion;

(iii) the legal requirements *re* notifiable diseases should invariably be observed;

(iv) milk and milk products should never be touched by hand, except where absolutely necessary, *e.g.* in cheese-making;

(v) surfaces of equipment coming into contact with milk after pasteurisation should not be touched by hand, or coughed over, etc., after sterilisation, *e.g.* mouths of washed milk bottles;

(vi) hands should be frequently washed and always after using the toilet.

See Cleaning and sterilising; Diseases, human; Food poisoning; Legal aspects; Management of dairies.

Refs.: Min. Food (1953), *Clean Catering*, H.M.S.O.; Hobbs (1953), *Food Poisoning and Food Hygiene*, London; Harvey and Hill (1952), *Food Hygiene*, London; Harvey and Hill; Savage (1949), *Public Health Problems*, London.

HYGIENIC QUALITY. *See* Bacteriological grading; Clean milk production.

HYGROMETER. An apparatus for estimating the humidity of the atmosphere. *See* Humidity.

HYPOCHLORITES. Commercial solutions of hypochlorites usually contain sodium hypochlorite in solution equivalent to about 100,000 p.p.m. of available chlorine (p. 222). For dairy use they are usually diluted to give a strength of about 200 p.p.m. Sodium hydroxide and sodium chloride are also present, the *p*H varying from about 10 to about 12.

Certain brands of hypochlorite are approved by the Ministry of Agriculture for the chemical sterilisation of dairy and farm utensils. All these contain 0·7 per cent. sodium chlorate to permit the detection of the hypochlorite if added to milk. *See* Chlorine; Cleaning and sterilising; Clean milk production; Corrosion; Disinfection; Metals; Water supplies.

Ref.: Botham and Dummett (1949), *JDR*, **16**, 23 (corrosion by Cl).

1

ICE CREAM. The introduction into England of a frozen confection purporting to be ice cream occurred in the reign of Charles I. Modern large scale production originated in America in the early part of this century and began to take shape in Great Britain just after the end of the first World War.

The terms *cream ices*, *ice cream*, and *ices*, are used rather loosely in Great Britain to describe frozen confections of widely different analytical composition, this confusion having arisen mainly because of the absence of any statutory definition of ice cream. In the U.S.A. each State has its own chemical standards for ice cream and there is also a Federal Standard. Canada, Australia, and many European countries have also enacted standards to which a product marketed as ice cream must conform; and in 1939 Northern Ireland and the Isle of Man introduced legislation defining ice cream.

Ice cream, cream ices, and ices, as distinct from sherbets, fruit and water ices (p. 529) in so far as Great Britain is concerned, are perhaps best considered as conforming in the main to two prototypes. Type 1 is essentially a *custard ice*, of low fat content, made from milk, stabilised with starch, and boiled during the mix-making process. Type 2, genuine *ice cream* contains at least 8 per cent. fat, and some 10 per cent. milk solids-not-fat, usually stabilised with gelatin, is pasteurised and homogenised during processing of mix, and invariably frozen in modern batch or continuous freezers.

Comparative analyses of typical examples of each category are as follows:

	Type 1 (*Custard ice*) (%)	*Type* 2 (*Ice cream*) (%)
Fat	3·00	12·00
Milk s.n.f. . . .	7·50	10·50
Sugar	13·00	13·00
Stabiliser . . .	3·00 (starch)	0·50 (gelatin)
Total solids . .	26·50	36·00

Type 1 (custard ice) is the sort of product favoured by individual traders. It is made in small batches daily usually in rather primitive equipment, and possesses initially poor texture which rapidly deteriorates.

Genuine ice cream (Type 2) is made to a correctly proportioned or "balanced" mix recipe or formula, and has a smooth permanent texture and rich creamy taste.

Ingredients. ***Type* 1 (*custard ice*).** The basic recipe from which this type of ice is made is as follows: full cream milk, 1 gal; sugar, 1½ lb.; cornflour, 6 oz.

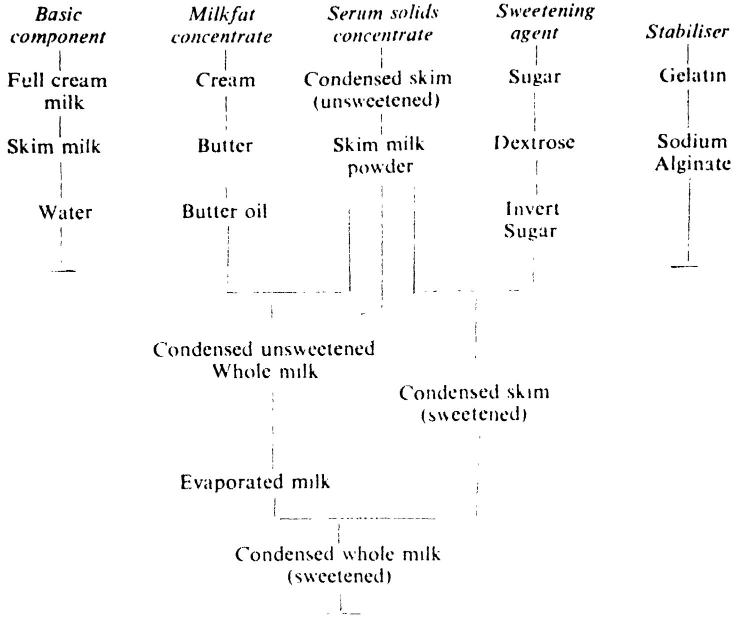
Shell eggs, or frozen or desiccated egg products are sometimes added in varying quantities to enhance the palatability of the products.

Proprietary ice cream powders are widely used in place of cornflour: such powders (hot process powders) consist essentially of cornflour, sometimes mixed with other starches. They are usually flavoured with vanilla and may be sweetened and sometimes contain a proportion of dried milk.

A few makers of this type of ice add cream, usually 50 per cent. fat content, to their mixture to enhance the quality of their product. Such an enriched custard ice, containing say a quart of 50 per cent. cream per gal. of mixture, becomes a good quality ice cream of about 13 per cent. fat content. The product is, however, "unbalanced", being deficient in milk S.N.F., and remains a starch stabilised, cooked, custard-flavoured product.

***Type* 2 (*ice cream*).** The ice cream mix constituents derived initially from milk are (*a*) milk (or butter) fat, (*b*) milk-solids-not-fat (serum solids), the remaining basic ingredients being a sweetening agent and a stabiliser. Obviously therefore, given modern processing and emulsifying plant, ice cream mix can be made up from a variety of dairy products. If the main bulk of liquid ingredient be regarded as the basic component, the ingredient rich in milk-fat called the milk-fat concentrate, and the ingredient used to augment the milk S.N.F. content regarded as the serum solids concentrate, then the relationship of the various ingredients can be schematically represented thus:

Schematic Representation : Ice Cream Ingredients.



From the diagram it follows that to a basic component (milk, skim milk) a milkfat concentrate (cream, butter) and a serum solids concentrate (skim milk powder, condensed skim) must be added in the requisite proportions to give with sweetener and stabiliser, a " balanced " mix of the required constitution. It will also be observed that some ingredients are classified as both fat and serum solids concentrates, *e.g.* condensed full cream milk ; while sweetened condensed products contribute sugar, as well as fat and milk S.N.F. to the mix.

A mix can be and often is compounded from milk, cream, and skim milk powder, alternatively, skim milk, condensed skim and butter can be used or again a " reconstituted " mix can be compounded from water, butter, and skim milk powder. Similarly, any of the " typed " ingredients within the scheme can be combined to give a mix, within the limits imposed by permutations and combinations. Of the dairy products listed, all are normally employed in mix making except butter oil and evaporated milk, though the latter commodity was specially released as an ingredient for ice cream in 1941. A good average quality dairy product ice cream should test from 10 per cent. to 12 per cent. milk fat and contain about 10 per cent. milk S.N.F. Rich ice creams may contain from 16 to 20 per cent. butter fat.

Plain vanilla ice cream of average analysis was originally known as *Philadelphia ice cream*, while ice creams containing eggs and often starch (cornflour) but of normal milk fat content, are known as *French* or *Neapolitan.*

Mousse is essentially sweetened cream (about 40 per cent. fat content) whipped and frozen in a batch freezer.

Parfait, and *ice cream puddings* invariably contain eggs, are often of fairly high fat content (18 per cent. fat), are enriched with a miscellaneous mixture of chopped fruits and nuts, and are usually highly flavoured.

Frappés, *soufflés*, etc., are essentially water ices (p. 529) and *punch* is a water ice flavoured with liqueurs.

The best all round dairy product ingredient combination is undoubtedly full cream milk, 50 per cent. cream, and spray process skim milk powder, but high grade skim condensed milk can be used as an alternative serum solids concentrate without loss in palatability of the product. Skim milk is widely used as a basic component in place of milk, and butter, preferably unsalted, was also a very popular butter (milk) fat concentrate in pre-war days.

Butter-oil and *plastic cream* (about 80 per cent. fat content) are both used to some extent in U.S.A. but not, as yet, in Great Britain. Sweetened condensed whole or skim milk can also be used, and were employed to some extent in the decade preceding the outbreak of war. Spray-dried skim milk can be recommended and vacuum roller powder is satisfactory, but atmospheric roller powder is unsuitable for use in ice cream.

Experimental evidence has been published indicating that condensed and desiccated milk products that have been subjected to high pre-heating temperatures prior to condensing or drying are preferable as serum solids concentrates in ice cream mix.

Frozen thick (about 50 per cent.) cream for ultimate use in ice cream can with advantage have 10 per cent. sugar added prior to freezing and refrigerated storage.

Edible grades of casein (some prepared by special methods) have been tested experimentally and put forward as ice cream ingredients.

Several methods of preparing de-lactosed serum solids concentrates specially for incorporation in ice cream mix have been patented. They depend either on enzymic hydrolysis of the lactose to glucose and galactose (more soluble than lactose) or on crystallisation of lactose from aqueous solutions of serum solids concentrates followed by removal of lactose crystals. (For significance of lactose in ice cream *see* " sandiness," p. 522.)

The addition of skim milk powder to partially frozen ice cream mix in the freezer has also been patented.

Sweetening Agents. *Sugar* (sucrose, saccharose) to the extent of 11 per cent. to 14 per cent. of the mix weight, is the normal sweetening agent used. *Dextrose* (glucose) (*Cerelose*) is extensively employed to replace up to one-third of the sugar content of the mix. Being only some 70 per cent. as sweet as sucrose, weight for weight, more dextrose is obviously required to give the same sweetness level, thus increasing the total solids of the mix and producing a smoother textured ice cream, though the frozen ice cream is softer and melts more rapidly than an all-sucrose product.

Saccharin was used in wartime ice cream in 1940-41 but has no place as a sweetening agent in ordinary ice cream. *Invert sugar* is occasionally used, but is not to be regarded as a normal ice cream sweetening agent. The equimolar mixture of dextrose and laevulose (or fructose) (" inverted " sucrose) is said to be sweeter, weight for weight, than ordinary sugar (sucrose) though the writer has failed to confirm this.

Stabilisers. The function of a stabiliser is two-fold, primarily, (i) to ensure a permanent smooth texture in the frozen and hardened ice cream, and also (ii) to assist in the production of a stable emulsion (ice cream mix is essentially an emulsion).

Gelatin is the traditional stabiliser most widely used both here and in U.S.A. The exact amount of any given grade of gelatin which is the optimum for a given mix formula, should be determined by experiment. It is that quantity which just fails to form any trace of gel in the processed mix after ageing for 24 hr. at 36° to 40° F. Powdered gelatin is now universally used. A good grade should be purchased, and 0·50 per cent. of the mix weight will be approximately the correct amount to use.

Gelatins are graded by the Bloom gelometer test, which measures the gel strength, under standard conditions, of the sample.

Powdered gelatin can be dissolved separately by the aid of moderate heat, and added to the mix in solution or mixed dry with some of the sugar and sprinkled on the surface of the warmed mix.

Edible sodium alginate (*Alginade*) is also employed to an increasing extent to replace gelatin. It is effective in concentrations of 0·2 to 0·3 per cent. of mix by weight, and reacts with soluble calcium salts to give calcium alginate which is insoluble in water and is precipitated in the form of a highly hydrated gel. Care is necessary in adding sodium alginate to a mix in order to ensure complete solution. The best method is to mix the alginate intimately with part of the sugar in the dry state, dusting the " mixture " on to the surface of the mix, which must be at 160° F., with the agitator running. Alginate stabilised mixes whip more readily and so far as the sodium alginate is concerned, do not need to be aged. Melting resistance is slightly reduced in alginate stabilised ice cream compared with gelatin stabilised products.

Gums, *Agar-agar*, *Pectin*, and *Irish Moss* (*Chondrus crispus*) have all been tried experimentally as stabilising agents. While all exercise some stabilising effect, and are well known as protective colloids in emulsion technology, none is as effective as gelatin in ice cream mix.

Gum tragacanth and *gum arabic* are employed in the manufacture of water ices, and Irish Moss was used in wartime " ersatz " ice cream with some success.

Emulsifying Agents. Egg yolk, frozen or dried, as well as whole egg products are invariably added to butter mixes to enhance their whipping ability, and are quite often incorporated in milk, skim milk, and other mixes. The main effect of egg yolk is to increase the stability of the mix emulsion and so give a mix of improved whipping and freezing properties. Dried egg yolk up to 0·5 per cent. and frozen yolk about 1 per cent. of mix weight are normal amounts used in ordinary ice cream.

Lecithin is also sometimes used, dissolved in the fatty phase, as also are synthetic emulsifying agents, *e.g.* monoglycerinstearate, etc., usually to the extent of 0·1 to 0·15 per cent. of mix weight.

Improvers. These were formerly in vogue, especially in America, as texture " improvers ". Products marketed for " improving " mixes are enzyme preparations, usually containing a rennet type of enzyme which acts on the casein in the mix causing a slight degree of " junketing ".

Improvers increase the colloidal viscosity of the mix, but it is doubtful if any significant improvement in texture results, and " improver treated " ice cream may show serious shrinkage during serving.

Antioxidants. Edible antioxidants (oat flour preparations) have been incorporated in mix in order to inhibit the development of rancidity in the fatty phase. Since the low temperatures at which ice cream is stored slow down enzyme catalysed reactions as well as oxidative changes to a very low rate, it is difficult to see the need for an antioxidant in ice cream unless a fatty ingredient is unwittingly used whose fat is approaching the end of its induction period, or, alternatively, an ingredient abnormally " rich " in lipase is used.

Vitamin Concentrates. Prior to 1939 several large British manufacturers fortified their mix with vitamin A and D concentrates; the level adopted by one company was that obtaining for margarine. Such additions are made entirely on nutritional grounds, and are valuable in view of the importance of vitamin D in calcium and phosphorus metabolism and the abundance of these elements in ice cream.

100 Per Cent. Fats and Oils. Prior to 1939, and entirely on the score of cheapness, refined vegetable oils, hydrogenated oils, and margarine were used to some considerable extent to replace part of the butterfat content of ice cream. Refined coconut oil, palm kernel oil, and hardened groundnut oil, were all used to provide in some cases up to 70 per cent. of the mix fat content. Following the outbreak of war in 1939, allocations of these oils were made by the Ministry of Food, and so in wartime ice cream they came to supply the whole of the fat content of the mix. Where butterfat standards for ice cream exist, it follows, of course, that such substitute oils and fats are ruled out.

Calculation of Formulae. The ingredient combination having been decided on, and the analytical constitution of the mix settled, calculation of the working formula is best accomplished algebraically by means of simultaneous equations. Limitations of space preclude a full presentation of the method of solution of simultaneous equations which can be found in any elementary textbook on algebra. The method of deriving the equations will therefore only be here indicated. Since three variables are introduced into the mix by the dairy product ingredients, namely, fat, M.S.N.F., and water, three equations will be required.

Assume the mix is required to have :

	(%)
Fat	12
M.S.N.F.	10½
Sugar	13
Gelatin	½
Total solids	36
Water (by difference)	64

Suppose it has been decided to utilise full cream milk, butter, and condensed skim as the dairy product ingredients (basic component, milkfat concentrate, and serum solids concentrate respectively) of the following analysis :

	Full cream milk (%)	*Butter* (%)	*Condensed skim* (%)
Fat	3·7	84	0·3
M.S.N.F.	8·8	1 [1]	27·5
Water	87·5	15	72·2

Since all the fat, all the M.S.N.F. and all the water in the mix must come from the above three ingredients, and we know from inspection of the required analysis, the total quantities of each of these entities present in 100 lb. of mix by weight, we can write the three appropriate simultaneous equations if we let :

a equal the weight of milk required per 100 lb. of mix ;
b equal the weight of butter required per 100 lb. of mix ;
c equal the weight of condensed skim per 100 lb. of mix.

Then, equating the percentage of fat in the three ingredients with that required in the mix, we get :

$$\frac{3 \cdot 7}{100}a + \frac{84}{100}b + \frac{0 \cdot 3}{100}c = 12$$

Multiplying throughout by 100 gives :

$$3 \cdot 7\,a + 84\,b + 0 \cdot 3\,c = 1200$$

Similarly as to serum solids (milk S.N.F.) we can write :

$$8 \cdot 8\,a + 1\,b + 27 \cdot 5\,c = 1050$$

And as to water likewise :

$$87 \cdot 5\,a + 15\,b + 72 \cdot 2\,c = 6400$$

---

[1] Can be assumed to be milk S.N.F.—actually " curd ".

Solution of these three simultaneous equations by the ordinary method of eliminating terms gives:

(*lb.*)
a = 54·30
b = 11·82
c = 20·38
Sugar = 13·00
Gelatin = 0·50

Mixed weight 100·00

From this 100 lb. batch, given that 100 lb. of mix equals for practical purposes 9 gal., a mix of any desired gallonage can be easily computed.

Equations for any other ingredient combination can be written in exactly the same way; the average analysis of the chosen components can be obtained elsewhere in this dictionary (pp. 274, 277 and 716).

With some ingredient combinations, the " water equation " can be replaced by one involving the total weight of dairy product ingredients added for:

$a + b + c =$ [total weight of mix (*i.e.* 100 lb) − (sugar + gelatin)].

This equation, where applicable, simplifies the arithmetic involved in solution of the simultaneous equations. It cannot be substituted for the " water equation " where sweetened condensed products are involved, as the " total dairy product contribution " to the mix cannot be known until the algebraic coefficients of the equations have been evaluated. It follows that the sugar to be added as such is the difference between the total weight of sugar required by the mix analysis, less that added in the sweetened condensed product.

There is a purely arithmetical method, known as the " Normal Serum " method, which can also be used to compute mix formulae; it is longer and more tedious than the method outlined above. The well known " Pearson Square " method can also be employed to calculate mix formulae from simple ingredient combinations; but is of restricted usefulness in ice cream technology. All three methods are given in full in comprehensive text books on ice cream manufacture.

Ice Cream Technology and its Underlying Colloid Chemistry. Ice cream mix, from whatsoever ingredient combination it is made, is simply and essentially an oil in water type emulsion. The disperse phase is milk (butter) fat, which has a low melting-point range and moreover contains some 5 per cent. or so of glycerides of the lower fatty acids. The continuous phase consists of a complex aqueous solution containing proteins and, in the case of casein, associated inorganic salts (calcium phosphate) in colloidal solution; the carbohydrates, lactose and sucrose (non-electrolytes) in true solution, as well as the inorganic (ionised) salts comprising the mineral matter or ash of milk.

This emulsion (or mix) has to withstand concurrently during the freezing process: (i) violent mechanical agitation; (ii) concentration of the continuous aqueous phase; (iii) aeration.

Mechanical violence tends to " break " an emulsion, concentration of the aqueous solution may lead to " salting out " effects of the proteins, while aeration causes denaturation of proteins; all three phenomena tend to reduce the stability of the mix emulsion. It follows, therefore, that ice cream mix must of necessity be a very stable emulsion.

Mix compounded from milk, cream, etc., will contain fat globules varying in size from 0·1 μ to 10 μ, and averaging 3 μ in diameter, while mixes made from butter contain, at the initial compounding stage, simply " massive " fat.

Homogenisation (or viscolisation) very considerably increases the degree of dispersion of the fat phase, the average fat particle size after efficient homogenisation is of the order of 0·3 μ or less. This increased sub-division of fat globules means that the number of individual fat particles per unit volume of mix is multiplied something like a thousand times compared to unhomogenised mix, with a correspondingly very large increase in the surface area of fat exposed to the aqueous continuous phase of the mix.

In any emulsion, surface active components are more or less readily adsorbed at the fat/serum interface; and in the mix, milk lipoids, egg yolk phospholipoid plus its loosely associated protein, synthetic emulsifying agents, *e.g.* monoglycerin stearate (if used), are all adsorbed in this way. Substances such as lecithin (milk and egg yolk phospholipoids), monoglycerin stearate, having a "polar" molecular structure are adsorbed and orientated in a monomolecular layer; the lipophilic end of the molecule projecting into the fat while the hydrophilic end extends into the surrounding aqueous phase.

Proteins (casein, lactalbumin and gelatin) are also adsorbed at the interface of the fat and watery solution.

This layer of adsorbed substances provides a sort of "envelope" of molecular dimensions which encloses the fat particles and has the effect of reducing the abruptness of the boundary between the immiscible fatty and aqueous phases.

There are two considerations of importance in ice cream technology connected with these phenomena: (i) This surface adsorption, following homogenisation, is not instantaneous. (ii) When established, this adsorption minimises the abruptness of the fat/serum junctions, "keying" the fatty and aqueous fractions of the mix together, so that the internal liquid cohesion of the mix as a whole is thereby increased. This increase in cohesion lessens the tendency of the mix to rupture when it is extended in thin lamellar layers during freezing and aeration.

The mix is able to stand up to the three-fold emulsion breaking effect of freezing on account of the enormously increased subdivision of the fatty phase consequent upon homogenisation, coupled with the "coating" of the individual fat particles with adsorbed layers, and the negative electric charge conferred on the fat particles by adsorbed ions.

The third effect during freezing which the ice cream mix has to withstand, namely, aeration, involves consideration of swell or overrun.

Overrun. This is defined as the increase in volume of the mix during freezing as the result of the "beating-in" of air, expressed as a percentage of the original volume of mix.

One gal. of mix which, after freezing, yields 1½ gal. of ice cream is said to have an overrun of 50 per cent.; if 2 gal. of ice cream had resulted, then the overrun would have been 100 per cent.

Mathematically:

$$\%\ \textit{overrun} = \frac{(\text{Volume of ice cream obtained}) - (\text{Volume of mix taken}) \times 100}{(\text{Volume of mix taken})}$$

or since weights are reciprocally related to volumes:

$$\%\ \textit{overrun} = \frac{(\text{Wt. of unit volume of mix}) - (\text{Wt. unit volume of ice cream} \times 100)}{(\text{Wt. unit volume of ice cream})}.$$

The maximum overrun obtainable and the speed of whipping, *i.e.* the "whipability" of mix, are important characteristics. Fat and gelatin tend to limit aeration, or in other words, depress overrun, while milk S.N.F. have the opposite effect.

During freezing, the air is incorporated in the form of minute spherical air cells surrounded by, and separated from each other by thin walls or lamallae of mix. The weakest point in these mix lamallae is located at the fat/serum interface, *i.e.* at the fat-aqueous junctions, hence the importance of the "bonding" effect of interfacial adsorption on overrun production.

The concept of maximum attainable overrun has been explained as a sort of dynamic equilibrium at which the loss of air, due to rupture of the mix lamallae consequent on over-extension, is equal to the rate of air incorporation by the dasher or other aerating device of the freezer. The optimum overrun is from

70 to 100 per cent.; less than 50 per cent. definitely yields a heavy, soggy, excessively cold product. Ice cream with an overrun much in excess of 100 per cent. is too light, fluffy, and unsubstantial.

The stabilising agent, gelatin, is added to mix mainly on account of the effect it exerts on ice crystal formation during freezing and hardening. This effect is to prevent the formation and growth of ice crystals perceptible by the tongue, so ensuring permanent smoothness of texture in the hardened ice cream. This effect is associated with " hydration " of the gelatin, ultramicroscopic micellae forming in the mix on standing at low temperatures.

There are, therefore, two important physical phenomena which occur in a mix subsequent to pasteurisation and homogenisation, both requiring time to go to completion. For this reason, the mix is aged, *i.e.* held at 36° to 40° F. for 6 hr. at least, after compounding, pasteurising, and homogenising, and prior to freezing. Ageing in excess of 6 hr., though accompanied by some increase in mix viscosity is unnecessary. It has been reported that ageing at 68° F. for 4 hr. is equally effective and, moreover, permits of a reduction of 25 per cent. or so in the mix gelatin content, but the practice has not been widely adopted.

Viscosity of Mix. Mix viscosity is differentiated into two types: (i) *real* or " *basic* " viscosity; and (ii) *apparent* or " *colloidal* " viscosity. The former is a function of the mix solutes and the fundamental emulsion structure of the mix, and is not significantly reduced by mechanical agitation.

Apparent or *colloidal* viscosity, as the terms used to describe it imply, is due to hydrated protein " structures " or aggregates formed in the mix, and to clustering of homogenised fat particles, where double stage homogenisation is not practised. Colloidal viscosity is rapidly destroyed by violent mechanical agitation; largely disappearing, for example, within a minute or two of the mix being introduced into a modern batch freezer. Basic viscosity, on the other hand, increases during freezing, due to the progressive concentration of the mix occurring as the result of the separation of the ice crystals. Contrary to earlier ideas, no relationship exists between the colloidal viscosity of the mix and smoothness of texture in the frozen ice cream. Mixes of high colloidal viscosity may be difficult to whip, particularly when due to post-homogenisation " clumping " of fat particles. This unwanted phenomenon is virtually completely eliminated by double stage homogenisation. Mix viscosity can be determined by means of a torsion viscometer (MacMichael viscosimeter) or in an Ostwald viscosity tube.

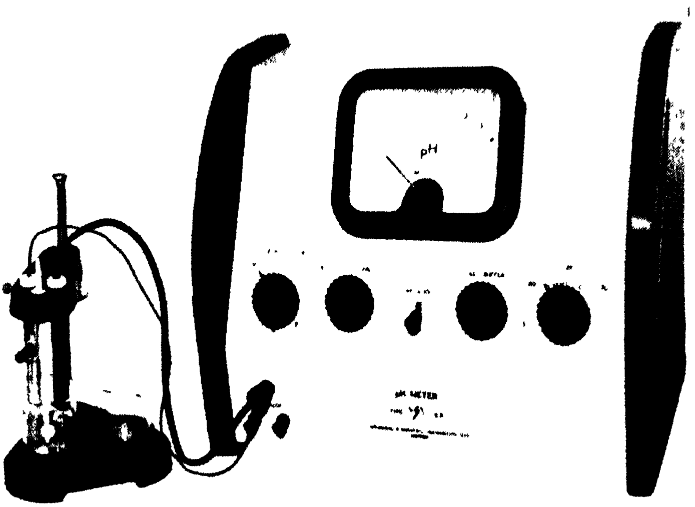
Surface Tension. Little is known about the technical significance of the surface tension of mix. Emulsoids such as gelatin increase surface tension, as do most inorganic salts. There is some degree of parallelism between the surface tension of a mix and the speed with which it whips to maximum overrun. The du Nouy apparatus may be used to determine the surface tension of mix.

Sandiness. The amount of serum solids that can be incorporated in ice cream is strictly limited by the lactose content. The S.N.F. of milk are constituted as follows:

	(%)
Protein (casein, lactalbumin, etc.) . . .	3·20
Lactose	4·70
Ash (mineral matter)	0·75
Other constituents	0·35
To give M.S.N.F. content of milk . . .	9·00

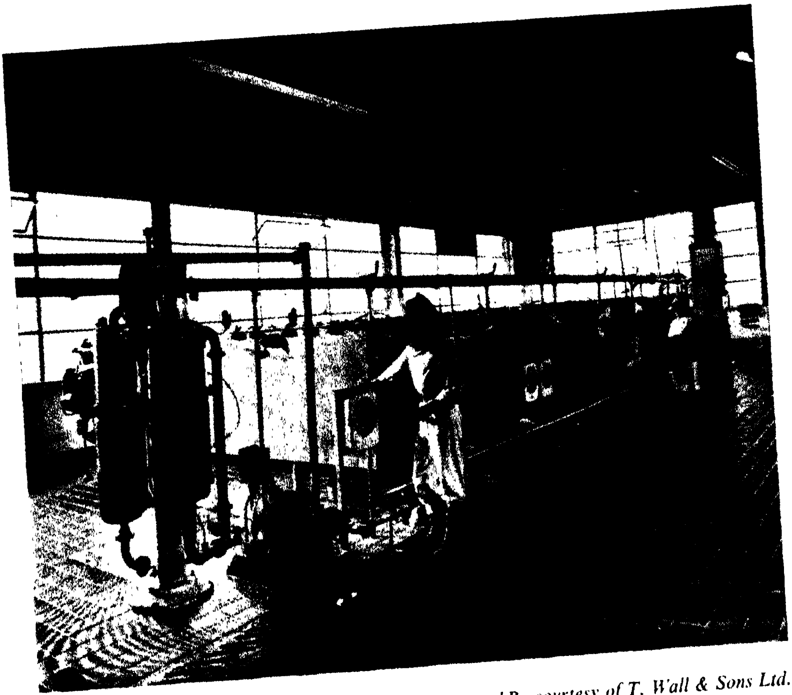
From this average analysis it follows that some 52 per cent. of milk S.N.F. is lactose (milk sugar). This carbohydrate exists in milk in two forms, and the lactose content of milk, and therefore of mix, is an equilibrium mixture of:

α Lactose monohydrate $\rightleftharpoons$ β Lactose anhydride.



[*By courtesy of Industrial and Scientific Instruments Ltd.*

FIG. Hy 1.—*p*H *Meter.*



[*By courtesy of T. Wall & Sons Ltd.*

FIG. IC 1.—*Pasteurisers for Ice Cream Mix. Each pasteuriser has a capacity of 450 Gallons of Mix. Vacreator in the foreground.*

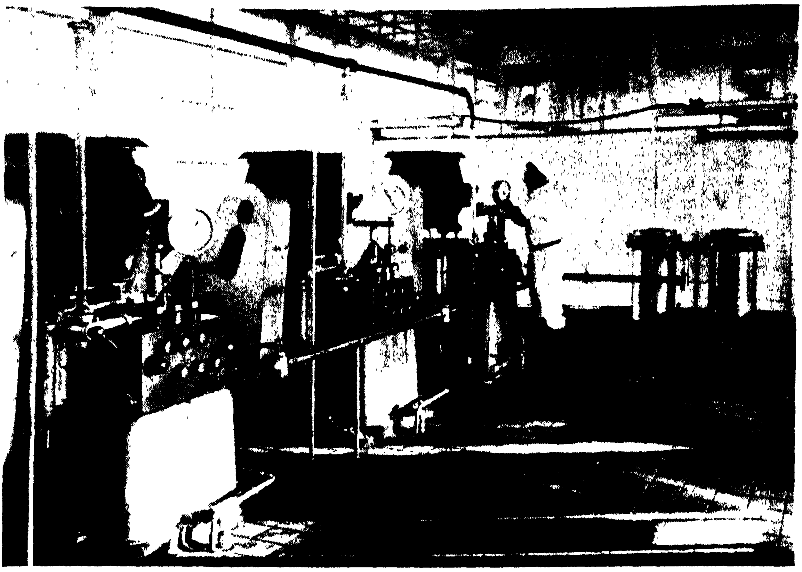


Fig. IC 2.—*Homogenisers. Normal working pressure 2000 lb. per sq. inch. Each handles 800 gallons of ice cream mix per hour. In the background, two mix strainers placed between the pasteurisers and the homogenisers to remove any undissolved matter.*

[*Photos by courtesy of T. Wall & Sons Ltd.*

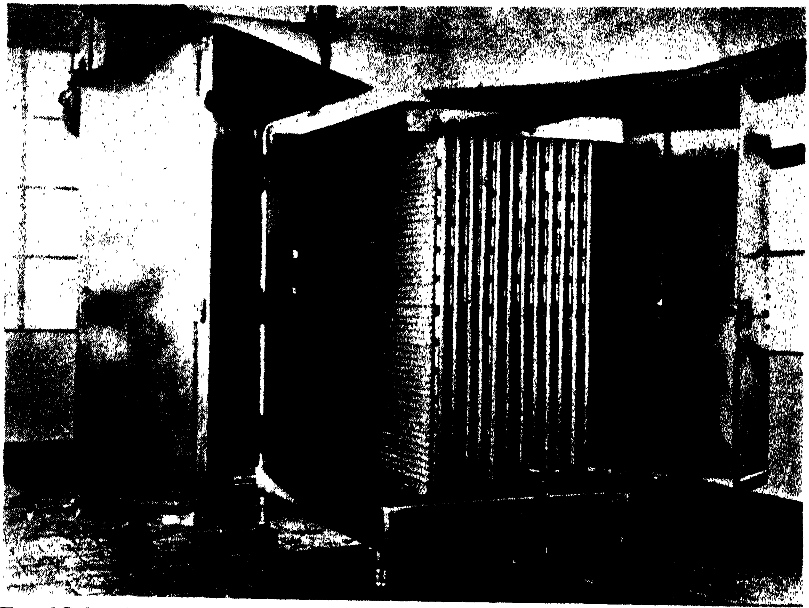


Fig. IC 3.—*Ice Cream Mix Cooler. Capable of cooling 2400 gallons of ice cream mix from 160° to 34° at one pass. The top half of the leaves is water-cooled, the lower half is cooled by direct expansion ammonia. The leaves open like a book for cleaning. The doors are closed when the cooler is being used. Fabricated entirely in Stainless Steel.*

The alpha hydrate is relatively insoluble in water and preponderates at ordinary temperatures; the beta anhydride is very soluble and is the only form of lactose which exists in aqueous solution at and above 93° C. (199° F.).

After heating up a solution of milk sugar (lactose) in water and cooling, some time elapses before the alpha hydrate-beta anhydride equilibrium appropriate to the lower temperature is reached. It is generally accepted that a ratio of lactose to water in mix greater than 1 to 12·5 may permit of subsequent crystallisation of the alpha hydrate with the development of the ice cream defect known as "sandiness", though lactose alpha hydrate crystals have to be 30 μ or larger before they are detectable by the palate. Sugar (sucrose), dextrose, and gelatin tend to suppress lactose crystallisation, as do high pasteurisation temperatures, followed by rapid cooling and minimum ageing prior to freezing. The effect of high pasteurisation temperatures is evidently to move the alpha hydrate—beta anhydride equilibrium to the right, resulting in an increase of the soluble anhydride at the expense of the relatively insoluble alpha hydrate, so reducing the danger of crystallisation occurring.

The maximum safe lactose-water ratio (1 to 12·5) given above, corresponds to a mix milk S.N.F. content of about 9½ per cent. Many years of practice have established that 10½ per cent. milk S.N.F. can be safely regarded as the maximum for ice cream mix without running the risk of sandiness developing. The additional 1 per cent. over and above the theoretical maximum is taken care of by the additive lactose crystallisation repressive effect of the agents mentioned above.

Heat shocking, *i.e.* fluctuations in temperature of hardened ice cream, favours the development of sandiness, and ice cream containing nuts is decidedly more prone to develop this defect than plain ice cream. Heat shocking probably initiates lactose crystallisation by causing alternate melting and refreezing of ice under static conditions, so causing a local concentration of lactose which crystallises out and so "seeds" the bulk of the ice cream, while the nut particles probably act as local centres of dehydration. The danger in the latter case can be obviated by soaking the nuts in sugar solution, or coating them with 5 per cent. gelatin solution prior to incorporation in the ice cream.

Effects of Salts on Mix. Two important effects exerted by the inorganic salts present in the ice cream mix have been studied in some detail. Mix made from dairy products relatively rich in sodium salts, has a low viscosity and whips readily, while a high proportion of soluble calcium salts exerts the opposite effect. Calcium ions increase fat particle clumping and decrease protein stability, addition of calcium precipitants, *e.g.* citrates, reduces fat particle clumping and viscosity, and increases protein stability. An irregular appearance, *i.e.* a "flecky" or partially curdled effect of melted ice cream, may be caused by an excess of calcium ions and can be prevented by the addition of fractional percentages of sodium citrate or of disodium hydrogen phosphate. High homogenisation pressures and a high fat to serum-solids ratio can also cause this defect which is fundamentally due to partial denaturation of the mix protein during freezing.

Freezing and Hardening. The freezing-point of average ice cream mix is usually taken as approximately 28° F. and since normal good practice is to feed mix into the freezer at about 34° F., the first stage in freezing is the removal of a small quantity of heat. Drawing temperatures for modern direct expansion refrigerated batch freezers (ice cream frozen "firm" to "hard") are 25·5° to 24·5° F. At these temperatures, some 38 to 45 per cent. of the mix water content has been frozen to ice; while at 23° F., 54 per cent. of the water exists as ice. It is obvious, therefore, that very roughly half the latent heat of fusion of ice is abstracted in the freezer, the remaining half of the water being frozen to ice in the hardening tunnel or room. During this freezing, the mix passes through a series of eutectic points since several different solutes are present. Probably the two most important from the technical point of view are the cryohydric (eutectic) points of sucrose and lactose, + 10° F. and + 24·5° F. respectively.

Though from these data it would appear that solid crystalline lactose and sucrose exist in ice cream, the available experimental evidence suggests that the lactose, at any rate, exists as a supersaturated, supercooled, solution. It is not improbable that the generally accepted optimum serving temperature for hardened ice cream, *ca.* + 10° F. is related to the cryohydric point of sucrose.

From the foregoing necessarily short review of the physical basis of the freezing process, the importance of effecting the maximum temperature reduction, consistent with adequate overrun production in the freezer, together with the equal desirability of rapid hardening in the hardening room, will be apparent.

Plant and Processing. Mixer-pasteurisers are fabricated from tinned copper, nickel, aluminium, or stainless steel, or made in so-called glass lined steel. They are usually water jacketed, and should not be direct steam heated. All mixer-pasteurisers should be fitted with an efficient agitator, thermograph, and be so designed as to permit of thorough and continuous, though not too violent, agitation of the mix during compounding and pasteurising. Internal helical coil vats are frequently used, the heating medium being circulated through the rotating coil which is usually fitted with small vanes, thereby providing the necessary agitation of the mix. Mixer-pasteurisers are available in sizes from 50 gal. upwards. The best material is undoubtedly stainless steel (Fig. IC 1).

The basic component is first run into the mixer, the heat and agitator turned on, and the temperature raised to from 100° to 120° F. Meantime the dry ingredients, sugar, milk powder (if used), and gelatin should be mixed intimately together in the dry state and then added to the warm basic component. The temperature is then raised to 160° F., the milk concentrate (cream, butter) added and also condensed products if included in the mix formula. From the time a homogenous mixture is obtained, the mix should be held steady at 160° F. for 30 min. (the recording thermometer checks time and temperature of pasteurising) then homogenised forthwith at pasteurisation temperature.

The hot mix should pass through a filter *en route* to the homogeniser in order to remove extraneous matter unavoidably introduced into the mix by its components, and also to protect the homogeniser valves, rams and cylinders, and also the homogenising valve(s) itself.

Some makes of homogeniser are fitted on the input side with metal gauze strainers ; in any event it is advisable to provide in the plant line-up a separate self-contained filter designed to take a renewable cloth filter. Such filters are standard items of ice cream equipment, either in the cylindrical or plate forms and can be obtained so made as to permit of instantaneous switching over from a clogged filter unit to a newly fitted unused cloth.

Homogenisation. Homogenisation (or Viscolisation) is essentially a physical process of fat globule sub-division, and is effected by forcing hot mix at high velocity through a small aperture. The orthodox machine used for this purpose is a three throw high pressure pump fitted with a spring loaded homogenising valve. The mix is forced at high pressure against the valve, and " lifts " it a thousandth of an inch or so off its seating, the mix thus escaping at high velocity through the small annular conical space between the valve and its seat. The fat globule splitting effect is ascribed in part to the shearing effect exerted on the globules spanning adjacent layers of mix or sub-microscopic proportions moving at different velocities ; and in part to the shattering effect of the impact of this very rapidly flowing stream of mix on the fixed housing of the homogenising valve.

Homogenisers (viscolisers) vary in detail design. The original Gaulin machines had an agate homogenising valve, but specially hardened steel is now commonly employed, while one very efficient machine utilises the " stretch " of a special metal tube to provide the clearance between the homogenising valve and its seat.

In some homogenisers the small apertures are provided by other means, *e.g.* serrated edges of metal plates arranged in juxta-position, capillary tubes with a spring-loaded ball valve at one end, etc. (Fig. IC 2).

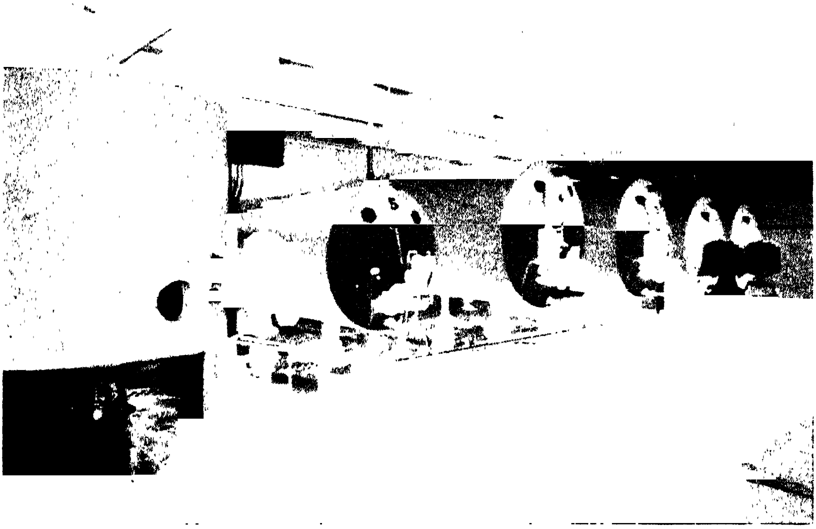


FIG. IC 4.—*Buffer Storage Vats (Ageing Vats). 5000 gallons capacity. Glass lined and cork insulated. Mix is retained in these vats until required for freezing.*

[*Photos by courtesy of T. Wall & Sons Ltd.*

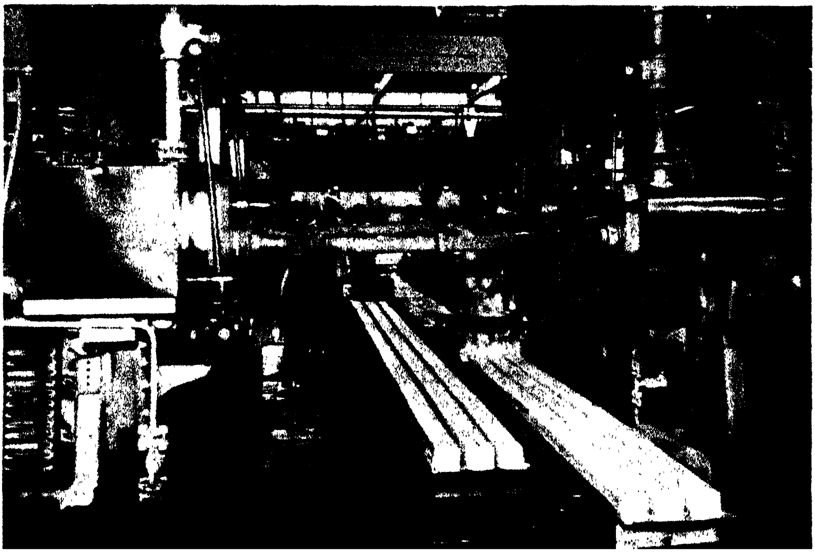


FIG. IC 5.—*Extruding Ribbons of Plastic Ice Cream from Vogt Continuous Freezers. The ribbons are hardened and subsequently cut and wrapped on " cut wrap " machines. See* Fig. IC 8.

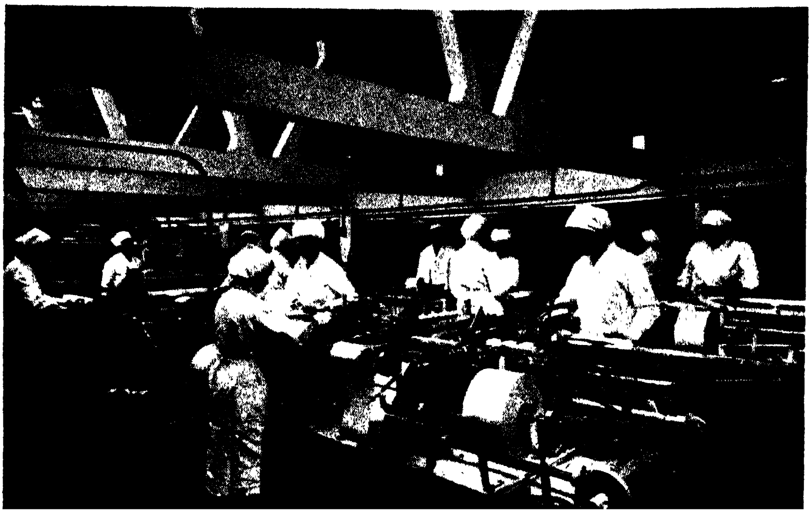


FIG. IC 6.—*Cut-Wrap Machines of Swiss Origin. These machines cut up hardened ribbons into brickette form and wrap them in paper taken from a reel. Capacity 60 per minute.*

[*Photos by courtesy of T. Wall & Sons Ltd.*

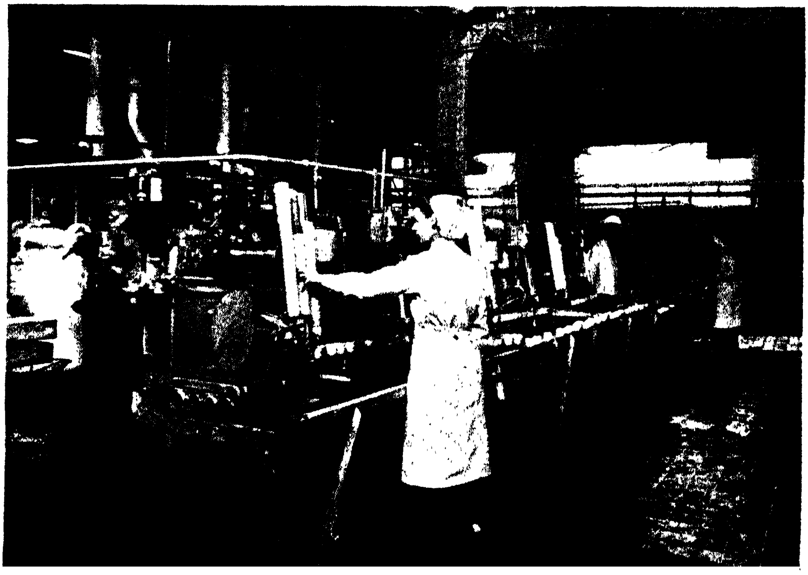


FIG. IC 7.—*Tub-Filling Machines Operating from Vogt Freezers. The tubs are hardened in a blast tunnel after filling and closing.*

Small capacity emulsifiers of varying design are also available. One type utilises centrifugal force to provide the mix velocity. Two steel discs, with hollow centres, are machined so that their circumferences are an accurate fit in the horizontal plane in which the discs rotate, the circumferential faces of the discs being held together by a fairly strong spring. When the steel discs are rotated at high speed, and the mix fed into their centres, centrifugal force flings the mix outwards to their periphery and forces the mix in a thin layer between the annular machined faces of the discs against the pressure of the spring so effecting sub-division of the fat globules, *i.e.* homogenisation or emulsification.

Another type of emulsifier consists of a direct driven rotor in the form of a three bladed screw which drives the mix through a perforated cylindrical sheet metal cover. Yet other types are provided with revolving rotors of different design ; none of these types appears to be effective unless it operates on a concentrated mix, and then it does not achieve the degree of dispersion effected by an orthodox homogeniser. In point of fact, from unpublished experiments made by the writer, the fat globule shearing effect appears to be a phenomenon intimately related to the constitution of the aqueous phase of the mix ; and while orthodox homogenising machines are effective where the continuous phase is normal milk serum, the less elaborate types just mentioned are definitely not.

Homogenisers (viscolisers) intended for use in ice cream processing should preferably be fitted with a double stage homogenising valve. The first stage valve should be operated at about 3500 lb. per sq. in., the second valve at 700 lb. to 1000 lb. per sq. in. Where a single stage machine is used it should, of course, be operated at the higher pressure.

Normal mixes of average analysis should be homogenised at 150° to 160° F. There is no advantage in cooling to 140° F. or less prior to homogenisation.

All orthodox type homogenisers should be fitted with a reliable pressure gauge (one for each stage in two-stage machines) and water cooling provided for the rams (pistons). Ample lubrication for the eccentrics and cross-heads is also essential. These are usually provided for in the design of the machine. The valves on both the suction and discharge sides of the machine should be accurately ground-in and so maintained ; the homogenising valve itself should be kept in good condition and free from " channelling ".

The power required to drive an homogeniser varies directly with the pressure, in fact, some operators rely on ammeter readings rather than on direct pressure gauge indication for guidance during processing. This is bad practice since mechanical defects, *e.g.* a " hot " bearing may throw an extra load on the motor and so give rise to an increased ammeter reading.

Mix viscosity decreases with increasing homogenising temperature and increases with increasing pressure with single stage machines.

The mix should always be heated to at least 155° F. prior to homogenisation in order to inactivate the fat-splitting enzyme lipase, otherwise off-flavours may be produced fairly rapidly if for any reason (*e.g.* condensing mix) the mix is held warm after it has been homogenised.

Mix coolers are illustrated in Fig. IC 3 and ageing vats in Fig. IC 4.

Freezing. Freezing exercises a vital influence on the texture and overrun of the hardened ice cream, in fact, it is hardly an exaggeration to state that an ice cream is " made or marred " in the freezer. The freezing technique varies with the type of freezer employed, the object in all cases being to secure rapidity of freezing to the lowest temperature practicable, consistent with the securing of adequate overrun.

The various sorts of freezers met with are listed below in chronological order of their appearance on the machinery market.

(i) *Ice and Salt Refrigerated Machines*, invariably vertical type, often hand operated though sometimes power driven.

(ii) ***Brine Freezers***, batch machines, usually horizontal type, some old vertical models still in use.

(iii) *Direct-expansion Freezers*, batch type, horizontal pattern, one model at least fitted with a triple dasher.

(iv) *Continuous Freezers*, direct-expansion refrigerated, as the name implies, are designed for continuous, not batch, operation.

Ice and salt freezers are usually of primitive design, and hand driven, and used only for freezing small quantities of ice cream, or more often custard ice intended for serving the same day as frozen and direct from the freezer can. The refrigerative effect is for practical purposes dependent on the ratio of ice to salt in the mixture. The proportion usually given is 4 to 5 parts ice to 1 part of salt, which gives a freezing mixture of about 2° F. though laboratory experiments by the writer have shown that 9 parts of ice to 1 part of salt are sufficient to secure this reduction of temperature in the freezing mixture.

With brine refrigerated freezers, a 25 per cent. calcium chloride brine is normally employed (3 lb. calcium chloride per gal. of solution which has a sp. gr. of approximately 1·2). The input brine temperature should be 0° F. and a rise of not more than 2° to 4° between freezer input and output brine lines should be tolerated. With these thermal conditions operating an adequate rate of brine flow is assured.

The time required to freeze depends on several factors, *e.g.* low (zero) brine temperature, adequate flow of brine through freezer, sharpness and accurate alignment of scraper blades, and correct dasher speed.

The condition of the scraper blades is very important and should be carefully watched. Dasher speed is normally fixed by the maker and varies from 140 to 270 r.p.m.

Under the optimum conditions outlined above freezing should take not more than 7 min. and whipping (with brine off) 3 to 5 min. These operational times are given as a guide, a little experimentation with any particular plant will soon disclose the best combination of freezing and whipping times to give adequate overrun and effective freezing.

Vertical freezers always yield less overrun than do the horizontal type machines and, excepting small capacity machines, are now quite out of date.

Direct expansion freezers have to a great extent superseded brine cooled machines. They are more efficient and freeze much more rapidly to a somewhat lower drawing temperature, thus giving a smoother textured product and increased freezing capacity for a given size freezer installation.

The speed of freezing depends on the temperature of the refrigerant (ammonia), back pressure, etc. (*i.e.* on the refrigerating plant) as well as dasher design, and speed and condition of scraper blades. Freezing time is ordinarily 3 to 5 min., while whipping to about 80 per cent. swell should not take longer than 2 min. under optimum conditions of freezer operation.

Various devices have been marketed for indicating the correct instant at which to draw ice cream from the freezer. One type depends on the increasing load thrown on the freezer motor, being in effect an ammeter, suitably calibrated, connected in the motor circuit, while another instrument measures the temperature of the partially frozen mix in the freezer.

The Mojonnier Overrun Tester is a separate piece of equipment which is in principle a balance so adjusted as to facilitate comparison of the weight of a constant volume of ice cream, the result being read on a scale calibrated in per cent. overrun. Provision is made for adjustment of the Tester for any given mix. The results are accurate and the determination takes seconds only to carry out.

Recording ammeters have been employed by the writer to control the operation of a number of freezers, and specially adjusted and calibrated " visual weight " scales of a well-known make were introduced with success to control the overrun of packaged ice cream in a large ice cream production unit some years ago.

Continuous freezers were introduced in a modern practical and efficient form to the industry some years prior to the outbreak of war. In contrast to all the types above described, and as the generic name implies, this newest development in freezer design permits of continuous freezing which, in turn, very considerably simplifies the planning and operation of continuous packaging plant line-up.

The Vogt continuous freezer consists of a mix receiving hopper provided with an agitator from which the mix is fed by two pumps, in series, to the freezer barrel. The air intake is capable of accurate adjustment thus enabling very close control of overrun to be continuously maintained. The relative speeds of the mix feed pumps can be varied within limits. The mix-air mixture is fed through the freezer barrel by the pumps, a rapidly revolving dasher, or " mutator ", provided with accurately machined scraper blades, being an integral part of the freezer barrel assembly. The frozen ice cream is extruded from the ejector end of the barrel in a continuous, semi-solid " stream " of any required shape depending on the cross-section of the extruder nozzle. Several models and capacities of each of the makes of continuous freezer are marketed, the larger model of one manufacturer being a double barrelled freezer of 250 gal. per hr. continuous rating. The Creamery Package Manufacturing Company's continuous freezer differs in some details but the principle is as outlined above.

Continuous freezers possess several technical advantages over the batch type, quite apart from the practical gains associated with continuous production units. The sojourn of the mix in the freezer is some 15 to 20 sec. only, during which short space of time, the mix is frozen to 22° to 23° F., which means that some 10 to 15 per cent. more of the mix water content is frozen to ice than can be achieved in the most efficiently designed and operated batch type freezer. Continuous freezers therefore produce ice cream of smoother texture than is obtainable with batch machines.

Direct extrusion is also practicable so that, given a hardening tunnel, freezing, packaging, choc-bar production, etc., followed by packing can all be accomplished on " continuous flow production " lines, leaving the hardening room for use as a storage chamber (Fig. IC 5).

As whole fruits, nuts, etc., cannot be passed through the continuous freezer since the clearances between mutator and barrel are much finer than in batch machines, special fruit and nut " feeders " are available through which these additions are " injected " into the frozen ice cream in the required, regulated quantities. Attachments are also provided through which either bulk, bricks, or cups can be filled direct from the freezer.

Continuous freezers are invariably direct-expansion ammonia refrigerated.

The alignment and sharpness of mutator scraper blades are a very important factor in maintaining freezer efficiency and output, and continuous freezers are rather sensitive to high ammonia back pressures.

Packaging. Ice cream is normally packaged into cups (cuplets) or " tubs ", and " brick " cartons of varying shape and size, as well as in the form of paper-wrapped slabs or slices. Several types of package filling machines are available, ranging from hand operated fillers and cappers to large multi-row power driven machines. Considerable space would be required to describe each type in detail ; the guiding principles in choosing a packaging machine are that it should be capable of handling well-frozen ice cream, and be so designed as to minimise both the mechanical and heat shocking of the product. Packaging machines vary in output from a few hundred to 10,000 packages (cups, etc.) per hr., the larger capacity machines the writer has had experience with, which were directly and continuously fed by twin continuous freezers with two differently flavoured ice creams (*e.g.* strawberry and vanilla), have proved extremely efficient, flexible, and reliable, while experience with smaller output machines has shown them also to be reliable and effective packaging units (Figs. IC 6, 7 and 8).

With the larger and more mechanically complex machines, as indeed with all ice cream plant, regular and skilled maintenance is very important in maintaining efficient production and plant output. Typical equipment for the small-scale manufacturer is illustrated in Figs. IC 9, 10, 11 and 12.

Hardening. Where output justifies it, and space permits, a hardening tunnel is undoubtedly the best method.

Modern practice in hardening room construction can be summarised as involving the flooded NH_3 system of refrigeration with " banked " evaporator coils (usually in the ceiling space of the room), forced air circulation, and low room temperatures (from – 20° to – 40° F.). Forced air circulation by means of large fans reduces hardening time by at least 50 per cent. compared to still air, with consequent speeding up of production and improvement in texture of the hardened ice cream.

It has been shown that single service fibre containers permit of more rapid hardening of contained ice cream than either paper or steel (tinned iron) cans, fibre surface being apparently a good heat radiator. It is obvious that close stacking and even worse, packing of freshly frozen and packaged ice cream into " outers " containing dozens of units (as is usual for transit) considerably slows the rate of hardening, *i.e.* freezing of remainder of water in mix to ice, with prejudicial effect on the texture of the product.

Even at very low hardening room temperatures, 1 or 2 per cent. of the mix water content remains unfrozen, while at 0° F. probably some 15 per cent. water is still present as such, and contains sucrose in approximately 50 per cent. solution. This explains the adverse effect of both slow hardening and also hardening room temperature fluctuations on ice cream texture.

Transit Refrigeration. The original method was the ice-salt mixture described under *freezing*. This rather messy procedure gave way to the use of insulated shippers (ice-less shippers, so called) which provided insulation but no refrigeration.

Then eutectic brine inserts were introduced, which consisted of metal containers of various shapes and sizes filled with the " eutectic solution " and sealed. One such solution the writer examined some years ago had the following composition and proved to be quite effective :

Calcium chloride . .	7½ lb.
Potassium chloride . .	2½ lb.
Sodium chromate . .	5 oz. (added to minimise corrosion of container)
Water	37 pints

The " inserts " are frozen solid in the hardening room and then placed in the insulated containers along with the ice cream ; from the fact that they contain a " eutectic " or " cryohydrate " it follows that the temperature remains at 0° F., until all the ice has melted. These inserts are, of course, refrozen and can be used indefinitely. The points against them are their weight, and the fact that they take up transport, as well as refrigeration capacity.

The modern shipping or transit refrigerant is, of course, solid carbon dioxide (dry ice), which is being widely and increasingly used by the ice cream industry both for refrigeration during transit and for conservators. Specially designed containers for the CO_2 permit of regulation of the temperature of the conservator sleeve within narrow limits.

Mechanically refrigerated motor trucks are used to some considerable extent in U.S.A. for the transport of ice cream from the plant to the point of sale ; insulated motor vans have been used in Great Britain for the same purpose and are sometimes refrigerated with solid CO_2.

Serving Ice Cream. Small, self-contained, automatic refrigerator cabinets with from one to eight ice cream container sleeves, as well as the CO_2 refrigerated " conservators " mentioned above, are ordinarily used to store the ice cream at the point of sale. Optimum serving temperature for both bulk ice cream and packaged goods is plus 10° F. Ice cream excessively aerated during freezing (too much overrun) will show " shrinkage " on standing ready for serving at this temperature.

Special Ice Creams. The variety of specially flavoured ice creams is wide; one or two only call for special comment here. *Fruit ice creams* should contain the appropriate fruit, though in the case of soft fruits a *purée* is sometimes used. The fruit added may be fresh or canned; in the former case, off-flavours occasionally develop, even when the fruit used is perfectly sound, due to enzymic activity. Fruit aromas or essence are invariably added to fortify the natural fruit flavour, and, of course, the ice cream is appropriately tinted by the judicious use of a suitable, harmless, edible colour. Synthetic flavours, if used at all, must be added very sparingly as they " show through " ice cream very readily indeed.

Chocolate Ice Cream. This is very popular in U.S.A. and was coming to the fore in Great Britain prior to the war. Cocoa powder is preferred as the flavouring agent in chocolate ice cream and is normally incorporated to the extent of 3 per cent. of the total mix weight. Dutch process cocoa (prepared by addition of alkali) does not interfere with the whipping properties of the mix, whereas domestic grades of cocoa depress maximum overrun and increase the time taken to whip. Many types of cocoa interact with the mix gelatin content, producing a gummy coagulum, the precipitant apparently being the tannins present in the cocoa, and this results in a poor texture in the hardened chocolate ice cream. As much as one-half of the gelatin may be so precipitated by certain grades of cocoa. Greenish discoloration may occur in chocolate ice cream as the result of the interaction of the cacao tannins, alkali, and iron, where this metal is exposed by scratches, etc., in the containers used to hold the ice cream. Cocoa is best added to the mix during compounding and prior to homogenisation; some manufacturers prefer to make up a chocolate syrup of composition somewhat as follows:

Sugar . . .	19 lb.
Cocoa . . .	13 lb.
Water . . .	4 gal.

Heat to 175° F. for 15 min. and use 7 lb. of syrup to 40 lb. of mix; and add at the freezer.

A trace of cinnamon, or cardamoms is sometimes added to enhance the chocolate flavour. Syrup, if used, should be freshly prepared each time required.

Chocolate Coated Bars. These achieved considerable popularity in Great Britain, and will undoubtedly remain a " best seller ". Ice cream " bars " of about 3 in. × 1½ in. × ½ in. dimensions are dipped in molten chocolate couverture, allowed to " dry " (harden), and wrapped, usually in decorated tin foil. Special couvertures are marketed by the chocolate manufacturers for this purpose, usually having a melting-point of less than 100° F. and giving 40 or more bars covered of approximately the above size per lb. of couverture.

Fractional percentages of lecithin added to the couverture avoid " thickening " due to the traces of moisture which eventually get into the chocolate " well " from the ice cream.

Small quantities of choc-bars can be readily produced by hand dipping, using specially designed forks or " prongs " for holding the ice cream while being dipped. Larger outputs require an automatic guillotine and dipping machine, while production on a really large scale requires an enrober.

Coffee, peppermint, ginger, banana, etc., flavoured ice creams were all available and can readily be prepared from flavouring agents marketed for this purpose.

Sherbets and Water Ices. *Sherbets* usually contain about 3 per cent. of milk fat, approximately the same amount of milk S.N.F., some 30 per cent. of sugar, 0·40 per cent. citric or tartaric acid, and are normally stabilised with 0·2 per cent. gelatin plus 0·2 per cent. gum tragacanth or agar. The product should be flavoured with fruit juice " backed up " if necessary with a high-grade essence of the appropriate flavour.

When gelatin alone is used as stabilising agent, overrun is difficult to control; the optimum swell for this type of product is 30 to 40 per cent. Where, for the sake of simplicity in compounding, gelatin alone is used, then overrun can be limited by over filling (*i.e.* 2/3 filling) the freezer with the sherbet mix, and freezing as rapidly as possible; or by removing the dasher from the freezer, leaving only the scraper to function. Where agar is used as joint (or sole) stabilising agent it should be dissolved separately in hot water, and the solution subsequently boiled for from 3 to 5 min. The gelatin, if used, can with advantage be dissolved, previously mixed with a little sugar, in the cooling agar solution prior to adding to the bulk of mix.

Glucose can, with advantage, replace ¼ to ⅓ of the sugar content, tending to retard the development of the defect known as " crustation ". This defect develops on the surface of the sherbet in the hardening room, and is due to crystallisation of sucrose. Covering storage in the hardening room materially reduces the tendency to " incrustation ".

The milk product components of sherbet, namely, milk fat and milk S.N.F. are frequently added to the sherbet syrup in the form of ice cream mix in the freezer.

Drainage of syrup, known as " bleeding ", from sherbet and water ices is another defect to which these confections are prone. It can be avoided by ensuring that the product is adequately stabilised. Obviously, the sherbet syrup mixture, once the stabilisers have been incorporated, should not be heated in the presence of the acid; in fact, the required amount of citric acid or tartaric acid is best added just prior to freezing, in the form of a 50 per cent. aqueous solution.

Water ices contain no fat or milk S.N.F., being, in effect frozen, diluted and sweetened fruit juices. Stabilisers such as gelatin or gums are usually added. The acidity may be increased slightly by the addition of citric or tartaric acid. Orthodox fruit ices are consumed shortly after having been frozen and have no " hardening room life ".

A variety of water ice in the form of a " frozen sucker " of triangular or circular cross section has been marketed widely and consists of a coloured, acidified fruit flavoured syrup run into moulds of appropriate shape and size, which are immersed in a brine tank and so frozen. The result is a coarse, icy product of very poor, rough, icy texture sold as a cheap line.

The following are representative sherbet and water ice formulae:

Milk Sherbet

Full cream milk or skim milk . . .	50 lb.
Sugar	20 lb.
Lemon juice	1 qt.
Gelatin	2 oz.
White of eggs	6 whites
Fruit juice (*i.e.* raspberry, orange, lemon, etc.)	4 qt.

If 50 lb. of water is used instead of milk, or skim milk and the egg whites omitted, a water ice results.

An alternative water ice formula is

Sugar (sucrose)	25 lb.
Dextrose	7 lb.
Agar	3½ oz.
Gelatin	3½ oz.
Citric (or tartaric) acid	7 oz.
Water, fruit juice, colour and essence .	67 lb.
	100 lb.

High Quality Sherbet

Sugar	33 lb.
Citric acid	½ lb.
Gelatin	3½ oz.
Gum tragacanth	3½ oz.
Ice cream mix	10 lb.
Water	56 lb.
	100 lb.

The ice cream mix can, with advantage, be added to the partially frozen " syrup " in the freezer. The addition of the casein-containing component of sherbets in the above manner, *i.e.* during the freezing of the syrup, minimises coagulation of the milk phosphoprotein by the acid present.

Bacteriology and Hygiene of Ice Cream. As is the case with all dairy products, ice cream production hygiene is fundamentally based on microbiology, and is considered from the dual aspects of: (i) " safety ", and (ii) " cleanliness ".

The first, " safety ", connotes freedom from viable pathogenic bacteria and is ensured primarily by efficient pasteurisation, and avoidance of post-pasteurisation contamination.

The second implies a satisfactory general bacteriological condition of the product, and this is a joint function of the microbiological quality of the ingredients used, the state of cleanliness, and efficiency of management of the plant itself.

Ice cream has been the cause of outbreaks of enteric disease and of food poisoning, and obviously can easily become the vehicle for conveyance of infection both of bovine and human origin.

Myco. tuberculosis bovis, *Brucella abortus* (causative organism of undulant fever) and haemolytic streptococci, can all gain access to raw ice cream mix from fresh or inadequately heat-treated dairy product ingredients and will survive in the frozen and hardened ice cream unless the mix is effectively pasteurised. Further, the highest grade of ice cream, namely, that made from cream, full cream milk, etc., is the most likely type to harbour these pathogens. All the data and arguments which overwhelmingly support the case for the pasteurisation of milk therefore apply with equal, if not greater force to ice cream, for freezing and hardening do not exercise any appreciable killing effect on bacteria, whether pathogens or non-pathogens.

Mix is usually pasteurised at 160° F., for from 20 to 30 min., mainly for technical reasons already discussed ; this higher temperature is, however, desirable on purely bacteriological grounds for it has been shown that sucrose (sugar) tends to exert a " protective " effect towards bacteria against heating. This higher pasteurisation temperature thus ensures that any pathogenic bacteria possibly present in the raw mix are definitely killed.

Custard type mixes, boiled during compounding, are, even more effectively, indeed excessively, heat-treated.

It is axiomatic that mix pasteurisation should be controlled by a thermograph which should, in turn, be frequently checked against an accurate thermometer, preferably an N.P.L. certified one.

There is a useful field for the application of a modified phosphatase test to the laboratory and public health control of mix pasteurisation.

Given efficient pasteurisation, *i.e.* mix held at 160° F. for 30 min. with gentle agitation, and avoidance of frothing, the result is quite certainly a mix free from living pathogenic micro-organisms, in other words, a " safe " mix.

Two further conditions are essential in order that post-pasteurisation contamination shall be avoided. First, steps must be taken to ensure that subsequent contamination of the mix by human agencies is precluded ; and second, that by rigorous methods of plant sterilisation, contamination from the plant itself is eliminated.

The first mentioned possibility can be excluded by avoidance as far as possible of all contact with the product by plant operatives, and by the intelligent planning of production and plant layout using closed circuits; and in the writer's opinion, and as an added safeguard, all plant operators and personnel handling the product should be bacteriologically examined to ensure that such people are not " carriers " of pathogenic organisms. As is well known, the general health of an individual is no criterion in this matter. The medical history of the persons concerned is useful, but the final surety is an appropriate bacteriological overhaul, at any rate, for enteric organisms. Unfortunately, there is no reliable bacteriological test which gives results in a reasonably short space of time, by which the presence of pathogenic bacteria can be detected in ice cream, hence the emphasis laid on preventative measures.

The circumstances are entirely otherwise in the case of plant contamination of the product; where tests, such as the plate or colony count on milk agar at 37° C. together with the presumptive coli test, do furnish a ready means of checking up on the sterility or otherwise of the plant. The results of these tests have an added significance, for where they indicate gross plant contamination it is a fair assumption that in the unhygienic state of affairs so revealed, opportunities will exist for contamination of the product to occur from the human sources mentioned above, if such " carriers " happen to be employed.

As a general guide, one or two principles of plant hygiene may be stated.

(i) After use, plant should be (*a*) rinsed through with cold or luke-warm (100° F.) water, (*b*) then with hot detergent solution.

(ii) Next, the whole plant should be taken down completely and scrubbed with detergent solution, rinsed well with hot water, and left ready for sterilisation.

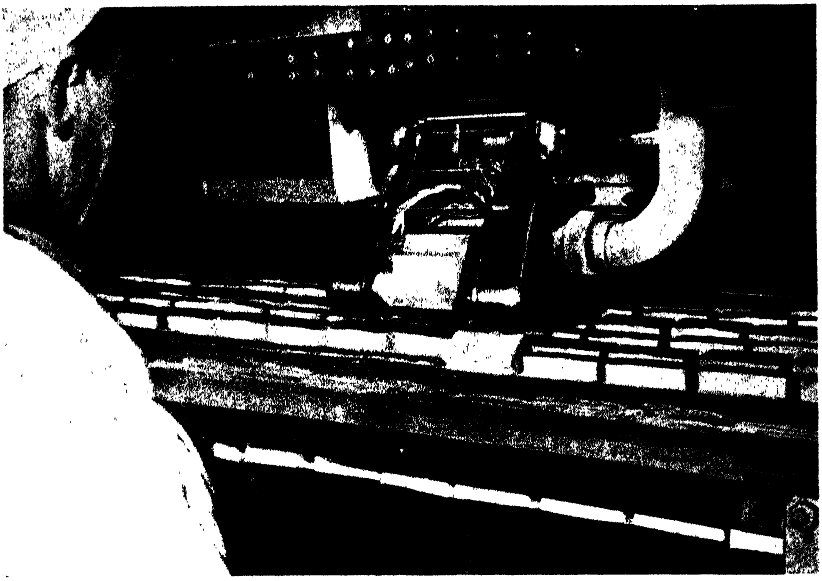
(iii) Plant sterilisation to be effective, should be carried out just prior to use, *i.e.* the first job each day in an efficiently managed plant is sterilisation. The reason for cleaning *after* and sterilising at the commencement of the day's run is obvious.

(iv) Steaming at 212° F. in a sterilising chest for 20 min. is effective where practicable. Pumping hot water, at 180° F. through the plant for 20 min. is equally satisfactory. Chlorine (as hypochlorite) using a strength of approximately 100 parts chlorine per million of rinse is also efficient if the plant has been thoroughly cleaned.

It is essential to loosen all blank ends, cocks, etc., so as to avoid any " pockets " where contaminants may exist and not come in contact with the sterilising medium.

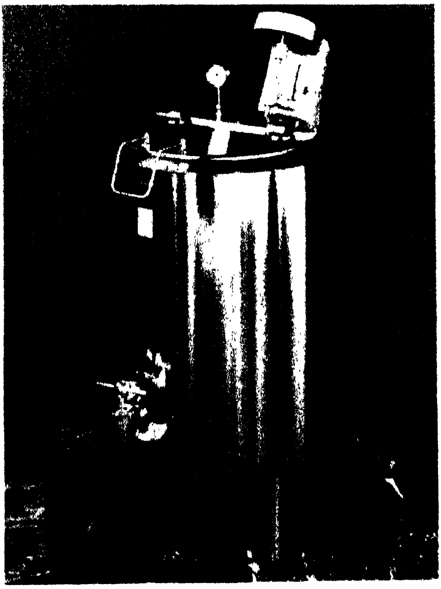
It is obviously essential to sterilise all metal ice cream cans and containers, all mix storage tanks, packaging machines, etc., paying particular attention to glands, pistons, and similar possible foci of contamination. Pump and paddle glands, homogeniser ram glands, dripless cocks, and similar points have all been found to cause contamination of ice cream and are sometimes difficult to locate as sources of contamination in the absence of laboratory facilities. Very occasionally the presence of large numbers of thermophilic or thermoduric micro-organisms in one or other of the dairy product ingredients has been found to be responsible for a high count in ice cream. Similarly, a heat-resistant strain of the coli-aerogenes group of organisms, able to survive 150° to 155° F. for ½ hr. has been isolated from ice cream mix. Both these possibilities are almost completely eliminated by pasteurisation at 160° F. for 30 min.

Bacteriological Standards and Interpretation of Micro-biological Data. There are no standards in Great Britain though they are in existence in U.S.A. (in some States) and vary from a maximum permissible plate or colony count at 37° C., of 100,000 to 500,000 per g. It is the writer's opinion, based on some



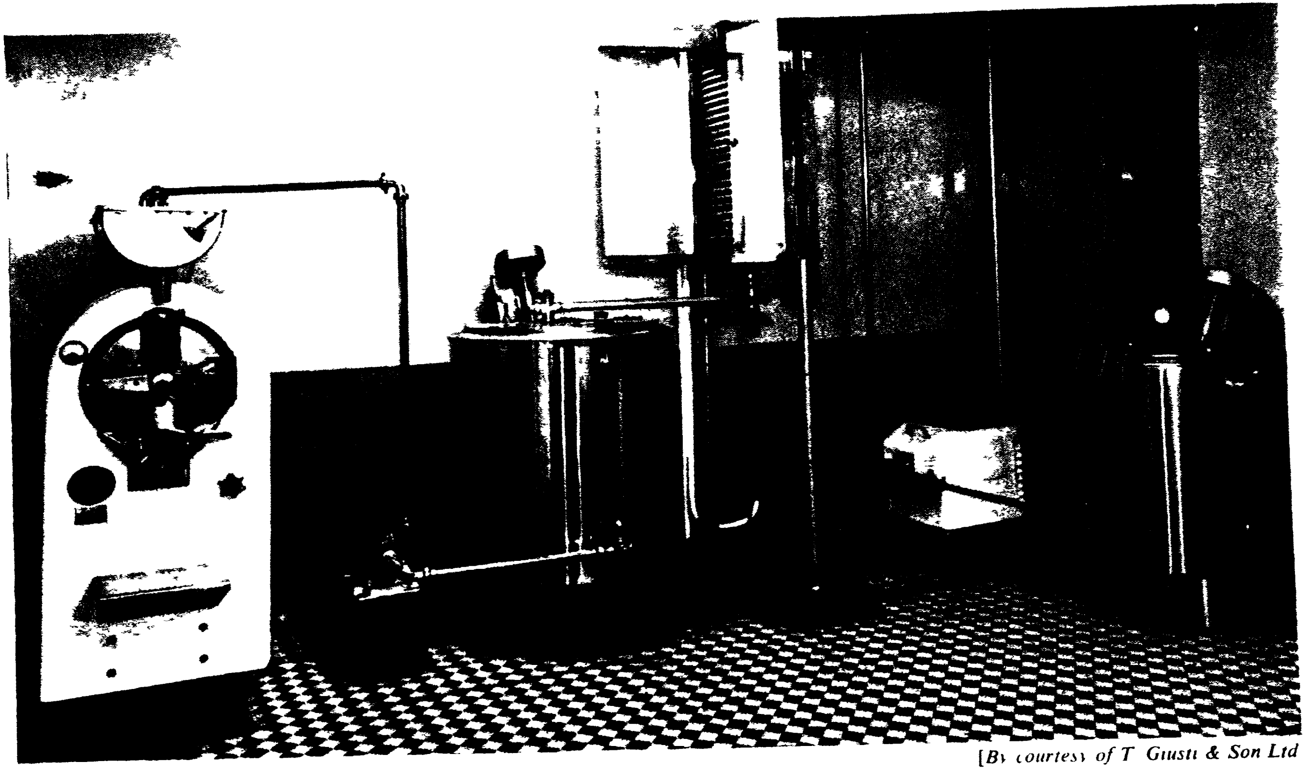
[*By courtesy of T. Wall & Sons Ltd.*

FIG. IC 8.—*Modern Brickette Production. The ice cream is extruded in a plastic condition and cut by wires as it leaves the extrusion nozzle, which moves backwards and forwards depositing rows of soft brickettes on to a conveyor belt. This belt moves backwards into a blast tunnel where the brickettes are hardened and then brought back to the front adhering to the underside of the conveyor belt where they are stripped and then wrapped at* 180 *per minute.*



[*By courtesy of T. Giusti & Son Ltd.*

FIG. IC 10.—*Small Heat-treatment Vat for Ice Cream.*



[By courtesy of T Giusti & Son Ltd

FIG. IC 9 —A Typical Small-scale Ice Cream Plant thousands of bacteriological examinations of ice cream over the last 20 years, that an ice cream, produced in an efficiently managed plant, need never contain more than 50,000 organisms, as enumerated by the plate count, and moreover rarely exceeds 20,000 bacteria per g.

Coliform organisms should be absent from 1 ml. of mix (or 1 g. of ice cream). The presence of coliform organisms, in the writer's experience, invariably indicates plant or utensil contamination. Though frequently not the case, cooked custard type ices should contain lesser numbers of bacteria per unit quantity than pasteurised dairy product ice cream. For a rapid test for coli *see* Borneff (1953), M **8**, 48.

While, theoretically, it is just possible to envisage an ice cream heavily infected with thermoduric organisms (*e.g.* spore-bearing bacteria) the writer has never encountered such a phenomenon in practice and in any case, a grossly contaminated ingredient or plant would thereby be indicated.

Laboratory Control of Ice Cream. Routine analytical control usually involves fat and total solids determinations. Various modifications of the centrifugal volumetric methods of determining fat in milk have been published for ice cream. None appears to be sufficiently accurate for production control. The only accurate method for determining the fat content of an homogenised ice cream is the Röse-Gottlieb technique. Total solids can be estimated by drying at 100° C. on a sand "support". Mojonnier, and Gallenkamp Ltd. (Technico Tester) have designed and marketed elaborate and compact equipments for estimating fat by this method and total solids by drying *in vacuo*. Both testers give accurate results in a matter of an hour or so.

Sugar(s) can be estimated by the usual inversion *cum* copper reduction methods, preceded by de-faecation. No readily applicable and accurate method is available for gelatin estimation. Egg yolk can be computed from a phospholipoid determination by the usual solvent extraction—wet combustion—molybdate phosphorus estimation.

Protein is estimated by the Kjeldahl method, ash by ignition, and *p*H most accurately by a glass electrode thermionic valve apparatus.

Overrun control is really a plant procedure. It can be estimated in the laboratory by weighing a known volume of ice cream, determining the sp. gr. of the remelted ice cream mix after ensuring all the air has escaped, and, ignoring the infinitesimal weight of the air, calculating from the formulae previously given.

Recent Developments. In exercise of the powers conferred on him by the Foods and Drugs Act, 1938, the Minister of Health made regulations (S.R. and O., 1947, No. 612), cited as the Ice Cream (Heat Treatment, etc.) Regulations, 1947, which came into operation on May 1, 1947.

These Regulations are of historic interest to the trade in Great Britain since they constitute the first indigenous, legislative enactments specifically dealing with ice cream.

Briefly, the Regulations require all ice cream, water ices, and similar products to be subjected to heat treatment adequate to destroy any pathogenic microorganisms possibly present; and subsequently to be cooled to a bacteriologically safe temperature within 1½ hr., and maintained thereat until frozen.

There is only one exception to this requirement, namely, in the case of a complete dehydrated cold mix which is reconstituted by the addition of wholesome drinking water only. Such a reconstituted mix must be frozen to ice cream within 1 hr. of being made.

Flavouring and colouring materials, including fruit, nuts, chocolate, "or similar substances" are specifically exempted from the heat treatment processes.

The local authority is empowered to require that recording thermometers be fitted to vessels used for the heat treatment, and/or for "ageing" or holding the cold mix until frozen; and the thermograph charts kept for a period of not less than one month.

This requirement as to provision of thermographs (Section 3(*b*), (IV)) is temporarily in abeyance because of the difficulty in regard to supply of the necessary number of such instruments.

The heat treatment specified (Section 3(*b*), (II)) is as follows:

(i) Mix must be held at 150° F. for 30 min., or (ii) at 160° F. for 10 min.

The Regulations contain two further provisions, first, any ice cream permitted to exceed a temperature of 28° F. following freezing, must be re-heat-treated prior to sale; and secondly (Section 5) all ice cream shall be protected from dirt, dust, and contamination at all times during manufacture, storage, and distribution; and further, all plant, apparatus, and utensils used in the manufacture, storage, or distribution of ice cream must (*a*) be thoroughly cleaned immediately after use, and (*b*) be kept clean at all times.

These requirements are comprehensive, but nevertheless just, and afford the Medical and Sanitary Officers of local authorities a considerable measure of control over the manufacture and sale of a commodity quite as much in need of careful and intelligent handling, and of independent supervision, as liquid milk.

The ice cream industry should welcome the regulations, since they are designed solely to ensure that the product shall be both as " safe " and as hygienically sound as it is humanly possible to make it.

The rigid, invariable observance of these regulations, together with a strict adherence to the details of personal hygiene will prevent a recurrence of the outbreaks of enteric epidemics, due to the consumption of infected ice cream, which have been an unfortunate feature of the last two seasons.

Apart from the responsibility which the manufacturer of any food owes to the public, the elimination of the periodic incrimination of ice cream as a cause of epidemic illness and the inevitable publicity such contretemps are given, can only rebound to the advantage of the industry as a whole.

Modified Methylene Blue Test for Ice Cream. The report of a Sub-committee of the Staff Committee of the Public Health Laboratory Service was published in the Monthly Bulletin of the Ministry of Health and the Public Health Laboratory Service, March 1947, p. 60.

This sub-committee report was titled " The Bacteriological Examination and Grading of Ice Cream " and it recommended an adaption of the Methylene Blue reduction test for assessing the hygienic quality of ice cream.

Briefly, the suggested test involves preparing a 1 in 5 dilution of ice cream with ¼ strength sterile Ringer solution, the 1 ml. Methylene Blue solution forming part of the diluent, any residual entrained air being allowed for by subsequent topping-up to the 10 ml. mark with Ringer solution.

The tubes are then subjected to a preliminary holding period of 17 hr. at 20° C. (± 0·5° C.) followed at once by incubation at 37° C. (± 0·5° C.) with the usual half-hourly inversion until decolorisation occurs.

Four grades are tentatively recognised as under:

	Time taken to reduce methylene blue
Grade 1	4½ hours or more
Grade 2	2½ to 4 hours
Grade 3	½ to 2 hours
Grade 4	0 hours (*i.e.* reduction at the end of the pre-incubation period)

Anomalous results are mentioned in the original paper, other workers have since (*a*) criticised, and (*b*) commended the test, which is now widely used by Local Authorities for the bacteriological examination of ice cream in Great Britain.

The original authors suggest that about 50 per cent. of samples examined throughout the year may be expected to fall into Grade 1, 80 per cent. in Grades 1 or 2, not more than 20 per cent. into Grade 3 and none into Grade 4.

They recommend that these criteria be adopted as a working basis, subject to possible modification in the light of further experience.

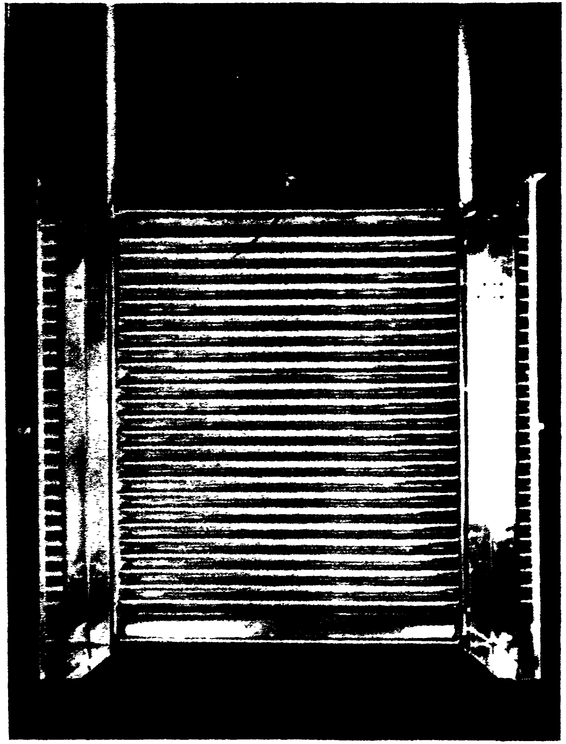


FIG. IC 11.—*Cooler with Hinged Covers.*

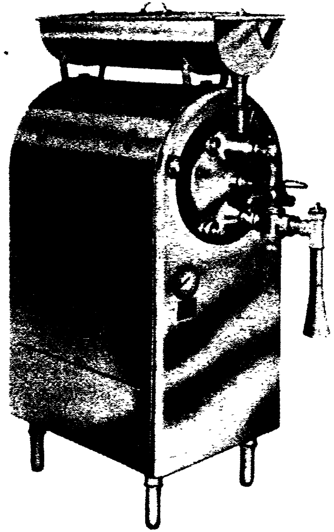
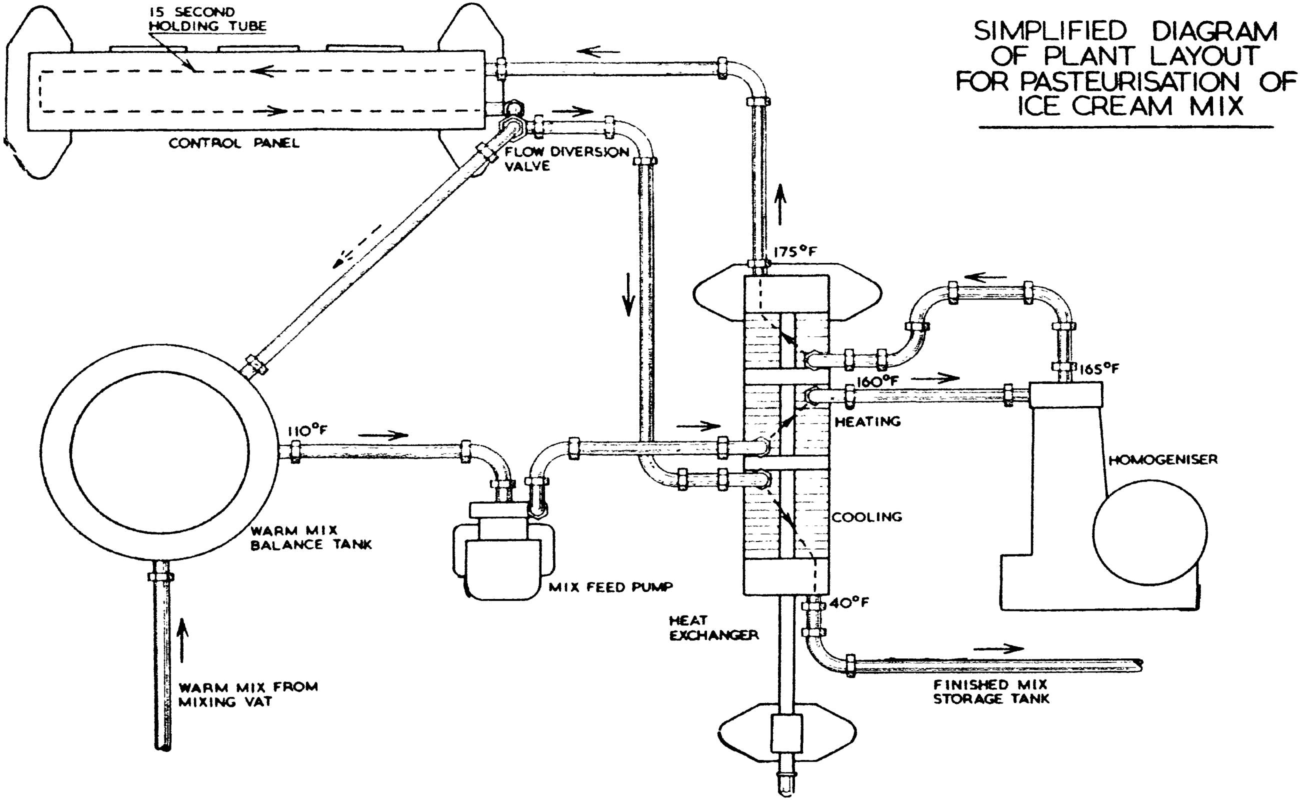


FIG. IC 12.—*Horizontal Pressure Freezer.*

[*Photos by courtesy of T. Giusti & Son Ltd.*



By courtesy of The A.P.V. Co. Ltd.

FIG. IC 13.—*The first H.T.-S.T. plant for ice-cream mix installed in Gt. Britain.*

H.T.-S.T. for Ice Cream. The Ministry of Health has recently made an Order which permits ice cream to be heat treated by the H.T.-S.T. method. This is effected by the Ice Cream (Heat Treatment, etc.) Amendment Regulations, 1952/815.

In future, the mixture can be heat-treated by one of the following methods:

Method I. The mixture shall be raised to and kept at a temperature of not less than 150° F. for 30 min.

Method II. The mixture shall be raised to and kept at a temperature of not less than 160° F. for 10 min.

Method III. The mixture shall be raised to and kept at a temperature of not less than 175° F. for 15 sec.

The apparatus used for subjecting the mixture to heat treatment by Method III must be thermostatically controlled and must be fitted with a positive displacement pump which shall serve to maintain the flow of the mixture during its retention at the prescribed temperature at an even rate, and also with a device which shall automatically divert the flow of any mixture which has not been raised to the prescribed temperature.

The first H.T.S.T. plant for ice-cream mix has now been installed in Gr. Britain (Fig. IC 13). (Brissenden (1954), *DI* **19**, 64.)

In a Ministry of Health explanatory memorandum reference Circular 14/52, it is stated that since there is no test analogous to the phosphatase test for milk available for ice cream owing to the variations in its chemical composition and ingredients, it is most important to ensure mechanical efficiency of the H.T.-S.T. plant.

Refs.: Turnbow, Tracy and Raffetto (1947), *Ice Cream Industry*, London ; Sommer (1951), *Theory and Practice of Ice cream Making* (1938), Madison, Wis. ; Cronshaw ; Mason (1939) *Fat, Total Solids and Moisture*, London; Wilster (1953), *IDC*, **2**, 459 ; England 465 (continuous pasteurisation) ; Thiel and Burton (1952), *DI*, **17**, 638 ; Botham, 640 (H.T.S.T.) ; King (1950), *DI*, **15**, 1052 (structure) ; Sjetne (1949) *IDC*, **3**, 242 (hardening) ; Sommer, 249 (sandiness) ; Hobbs (1951) *JRSI*, **71**, 413 (public health aspects); Reid (1951), *D*, **68**, 23 (costings); Webb (1948) *JSDT*, **2**, 27; Bogod (1949), *IDC*, **3**, 232 (manufacture); Thiel and Burton (1952), *MBMH*, **11**, 78; Botham, *MBMH*, **11**, 82 (pasteurisation of mix); *MBPH* (1948), **7**, 84; (1949), **8**, 155; (1950), **9**, 231 (*MB* and coli); Patton (1950), *SAB*, **13**, 100 (bact. tests); Jones-Evans *et al.* (1949), *SAB*, No. 1, 25 (replicate samples); Hutchinson and Chetham (1949), *D*, **66**, 135 ; Clayson and Pirie (1948), *JSCI*, **67**, 147 ; Watson *et al.* (1947), *SAB*, p. 58.

ICELAND.

Ref.: Tryggvason (1949), *IDC*, **5**, 169.

IDENTIFICATION OF BACTERIA. *See* Classification.

IMMUNITY. Immunity or the ability of an organism to resist the invasion of a pathogenic micro-organism or the onset of a disease, is due to the presence of certain substances in the blood. It is well recognised that recovery from certain diseases gives an individual a resistance against that disease or immunity from a second attack. This immunity is specific for the disease in question and may be permanent, temporary, or partial. Many factors such as individuality, health, nutrition, etc., affect the degree of immunity.

The introduction of foreign substances or *antigens* into the tissues of an animal stimulates the production of *antibodies*, which can react and neutralise each other specifically in the animal or *in vitro*. The specificity is dependent upon the chemical nature of both antigen (usually a protein) and antibody, and the immunological specificity of the antigen is determined by a relatively small fraction of the large protein molecule. This simple part of the complex is called a *haptene* or *partial antigen*. An immune serum or *antiserum* contains antibodies which may exert five distinct types of effect : (i) *anti-toxins*—neutralising the poisonous effect of the toxins ; (ii) *lysins*—" lysing " or dissolving the foreign cells, *e.g.* bacteria ; (iii) *opsonins*—substances which render bacterial cells susceptible to the devouring by the phagocytes or white blood cells ; (iv) *agglutinins*—immobilising and aggregating the foreign bacteria ; (v) *precipitins*—substances which precipitate soluble antigens. The antibodies are, or are associated with, the globulins of the serum proteins.

Refs.: Jordan and Burrows (1949), *Textbook of Bacteriology*, London ; Wilson and Miles.

IMPROVERS. *See* Ice cream.

INCIDENCE OF BACTERIA IN DAIRY PRODUCTS. *See* Bacteriological grading; Clean milk production; Coliforms; Cooling; Flavours; Lactic acid bacteria; Quality payment; Stability; Thermoduric and Thermophilic bacteria, and the various specific faults and dairy products.

Refs.: Chalmers ; Hammer ; Orla Jensen ; Rogers.

INCUBATION. The holding of samples of milk at atmospheric shade or a fixed temperature, *e.g.* 18° C. for a period, *e.g.* 18 or 24 hr., before applying a bacteriological test. *See* Bacteriological grading of milk ; Legal aspects ; Milk (Special Designations) Orders ; National Milk Testing and Advisory Scheme.

INCUBATION PERIOD. The period elapsing between infection and the appearance of symptoms of the disease.

INCUBATORS. The following sources of error in " temperature range of growth " experiments have been observed : (i) incorrectly adjusted incubator ; (ii) fluctuations in temperature ; (iii) time lag in media placed in incubator ; (iv) difference between temperature in region of thermometer and that of media ; (v) cooling effect of evaporation of moisture from media.

(ii) Fluctuations may be minimised by shielding the incubator from draughts. High temperature (37° C.) incubators should never be placed in corridors or near doors. A special room or a cul-de-sac is the most suitable position for such incubators.

(iii) As an example of the time lag may be quoted an experiment in which it was found that tubes of litmus milk required 21 hr. to attain an equilibrium temperature of 50° C. in an incubator. For all temperatures below 22° and over 37° the media should be raised (or lowered) to the experimental temperature before inoculation. This is most conveniently done by leaving the media in the incubator for 24 hr. previously. If this is impossible they should be immersed in water at the required temperature.

(iv and v) The control thermometer should be mmersed in water in a plugged test tube, or in agar, and placed with the experimeintal tubes or plates. Evaporation may be minimised by placing a flask of water in the incubator.

INDIA.

Refs.: Sen and Laxminarayana (1953), *DSA*, **15**, 921; Warner (1951), *Dairying in India;* Singh (1949), *IDC*, **4**, 598 ; Dasgupta (1945), *The Cow in India*, Calcutta ; Davies (1940), *Indian Indigenous Milk Products*, Calcutta ; Wright (1937), *Report on the Development of the Cattle and Dairy Industries of India*, Delhi ; Brissenden (1952), *JSDT*, **5**, 108 ; Sen 115 ; Kay (1946), *Rep. Dairy Res. India*, etc., New Delhi.

INDICAN. A nitrogenous substance alleged to be present in milk under certain pathological conditions.

INDICATORS, pH. *See* Acidity ; Hydrogen ion concentration ; Media. p. 461.

INDICATORS, rH. Certain dyes change colour when reduced or oxidised and so may be used to measure the change in the state of oxidation or reduction in a solution. The most useful are :

	O/R potential at pH 7
2 : 6 dichlorphenol indophenol	0·181
Toluylene blue	0·115
Thionine	0·062
Methylene blue	0·011
Indigo tetrasulphonate	– 0·046
Indigo trisulphonate	– 0·081
Indigo disulphonate	– 0·125
Phenosafranine	– 0·252
Neutral red	– 0·325

These values are volts at E_0 for *p*H 7, *i.e.* the potential at which 50 per cent. of the dye is reduced. The useful range is $E_0 \pm 0{\cdot}05$ v. *See* Oxidation-reduction potential.

Refs.: Clark *et al.* (1923-26), *Studies on Oxidation-reduction*, N.Y.; Clark; Hewitt (1950), *Oxidation-reduction Potentials in Bacteriology and Biochemistry*, L.C.C.

INDIVIDUALITY OF THE COW. Like all animals cows vary individually in all properties, including the quality and quantity of milk they secrete. The smaller the number of cows in a herd, therefore, the more liable is the farmer to experience trouble over compositional quality on any one day. *See* Composition, factors affecting.

INDOL, PRODUCTION BY BACTERIA. *See* Classification; Coliforms.

INDONESIA.

Ref.: Ursone (1949), *IDC*, **5**, 173.

INFANT FOODS. Physiology of Infant Digestion. In order to facilitate discussion of infant foods and infant feeding, it would be well to review some of the more important aspects of the digestive physiology of the child. Essentially the digestive process in infancy does not differ from that of the adult, but there are one or two points of significance. The process of digestion in the adult and older child normally begins in the mouth, where the enzymes of the saliva start the splitting of starches present in the food and the process is continued during the subsequent stages in the passage of the food through the alimentary canal, a new series of carbohydrate splitting enzymes making their appearance at the small intestine stage where the digestive process is completed. For the first few months of life the saliva is deficient in starch-splitting enzymes, so that the whole process of carbohydrate digestion must take place in the small intestine. Because of this, starch-containing foods are not generally suitable in early infancy. The second stage of digestion is completed in the stomach, where there are two enzymes that act upon protein. The first is rennin, which coagulates milk, converting it into a curd, and the second, pepsin, then acts upon the coagulated protein and begins the processes of splitting it up. Both these enzymes are effective only in an acid medium, and the stomach secretes hydrochloric acid to produce such a medium. During infancy the total amount of hydrochloric acid secreted is not large, and under certain circumstances, including even minor illnesses, the acid secretion may diminish quite considerably, or even disappear for a time altogether. This hyposecretion must obviously interfere with the normal process of digestion. On leaving the stomach, the partly digested proteins and starches enter the small intestine, where in an alkaline medium proteolytic and amylolytic enzymes complete the breakdown of these substances, and fats are also digested by the lipolytic enzymes. From the small intestine the end-products of these digestive processes are absorbed by the blood and lymph streams and transported to the general tissues of the body. All three types of enzymes are present in the small intestine during infancy, so that all categories of foodstuffs can be dealt with, but it is important to realise that a very significant degree of digestion should take place normally in the stomach and from the age of a few months onwards, also in the mouth.

General Nutritional Requirements. Undoubtedly the ideal food for the human infant is human breast milk, which has the important nutritional advantages that it is secreted ready warmed and sterile, and perfectly balanced in proteins, fats, carbohydrates, vitamins and minerals. Of this fluid the healthy infant consumes 2½ fl. oz. per lb. of bodyweight per day, and as human milk has a calorific value of 20 cal. per fl. oz., this represents a daily intake of 50 cal. for each lb. of bodyweight. Unfortunately, there are occasions when a substitute for breast milk must be found, and in these instances resort is normally made to cow's milk in some form or other. Although cow's milk also has a calorific value of 20 cal.

per fl. oz., it is not suitable as a direct substitute for breast milk, because its composition differs significantly in several ways, as the following table shows:

COMPOSITION OF HUMAN AND COW'S MILKS (PER CENT.)

	Water	*Fat*	*Sugar*	*Casein*	*Albumin*	*Total Protein*
Human	87·6	3·8	6·4	0·8	1·2	2·0
Cow .	87·3	3·7	4·9	2·9	0·5	3·4

Apart from the fact that the nature and constitution of the proteins differ in the different species, there is a higher proportion of protein and a lower proportion of sugar in cow's, as compared with human milk. Furthermore human milk contains nearly three times as much albumin and rather less than a third of the less digestible casein that is present in cow's milk. Moreover, cow's milk is deficient in iron and in vitamin D, so far as the nutrition of the human infant is concerned, and as cow's milk is always boiled or otherwise subjected to heat before use as an infant food, a considerable proportion of the vitamin C content may be destroyed. It is therefore apparent that cow's milk must be modified and supplemented in order to make it suitable for feeding to infants. So far as supplementation is concerned, vitamin C is usually supplied to artificially fed infants in the form of fruit juices such as orange, tomato or black currant, and vitamin D is given as a fish-liver oil or a synthetic vitamin concentrate. After the first few weeks when the reserves of iron present in the body at birth have been used up, this element is usually prescribed separately as one of its salts. The modification of cow's milk to make its composition in respect of proteins and carbohydrates approximate more nearly to that of human milk must be discussed separately, depending upon the particular form in which the milk is obtained. The ultimate aim of all methods of modifying cow's milk is to produce a well-balanced fluid containing about 20 cal. per fluid oz. in order to supply the necessary quota of body building materials and to secure at the same time a minimum fluid intake of 2½ fl. oz. per day for each lb. of bodyweight.

Underweight infants should be fed according to their expected rather than to their actual weights. The usual practice is to give five four-hourly feeds in the day, but in the first few weeks some smaller babies do better on six three-hourly feeds. However, the present trend is not to be too rigid in the timing or the volume of the feeds, but to feed "on demand". Most babies soon settle down to a routine that satisfies their own individual requirements.

Milk and its Preparations used in Infant Feeding. Wherever whole milk, either as fresh liquid milk, as a full-cream powder or as a full-cream evaporated milk is used as a basis for infant feeding, it can be made to approximate in composition, at least sufficiently for all practical purposes, to that of human milk. This can be done by simple dilution with water in order to reduce the proportion of protein, and then adding sufficient carbohydrate to bring the sugar content nearer to that of human milk. For this purpose cane or beet sugar is most widely used and is entirely satisfactory. Mixtures of maltodextrin are sometimes employed, but the use of lactose or natural milk-sugar is quite unnecessary.

(*a*) ***Liquid milk.*** Fresh liquid milk which has been boiled in order to rid it of pathogenic organisms, especially the tubercle bacillus if it should happen to be present, and allowed to cool forms a satisfactory basis for infant feeding. A commonly employed formula is as follows:

Fresh boiled cow's milk . . .	1¾ fl. oz.	= 35 cal.
Boiled water	¾ fl. oz.	
Sugar (level teaspoonful) . . .	1 drachm	= 15 cal.
Total	2½ fl. oz.	= 50 cal.

Of this mixture the total daily requirement, calculated as described above in accordance with the weight of the child, is divided as a rule into 5 or 6 equal and separate feeds. The proportions suggested may be maintained until the infant weighs about 15 lb., after which the strength of the mixture must be increased in order to provide for the intake of more fat and less sugar.

Another method very commonly used after about the first month is to calculate the total daily intake of fluid required by the infant in question. This is then divided into 5 equal amounts. One fl. oz. *less* than this quantity of cow's milk is taken, and to it is added a teaspoonful of sugar and one fl. oz. of boiled water, the resulting mixture comprising one feed thus:

Weight of Infant, say, 12 lb.	
Daily requirement of fluid 2½ × 12 fl. oz.	30 fl. oz.
Fluid required at each of 5 feeds	6 fl. oz.

This is provided as cow's milk 5 fl. oz., boiled water 1 fl. oz., sugar 1 teaspoonful. This method of using liquid milk has the advantage that the strength of the mixture and the proportion of fat and protein are automatically increased as the child grows older and is able to tolerate them. By the age of 5 months or so, undiluted cow's milk can be employed.

(*b*) ***Dried milk powders.*** While fresh milk is nutritionally a satisfactory basis for infant feeding, there are often other objections to using it. Among these may be mentioned the facts that it may be difficult to keep it from souring, especially in warm weather; that it is difficult to maintain it free from contamination with harmful bacteria, and that it must be boiled before use. Moreover, in certain parts of the world fresh cow's milk may be virtually unobtainable or obtainable only from a dubious source. For these reasons, and because of their convenience in handling and capability of being stored for long periods without deterioration, dried milk powders are coming more and more into use.

Both the spray dried and the roller dried types of milk powders are used in infant feeding, but perhaps the latter are more widely employed because they are cheaper to produce and because the roller drying process so alters the nature of the protein that it forms a fine flocculent curd in the infant's stomach, very similar to that formed by human milk, as distinct from the hard and tough curd produced by untreated cow's milk.

Dried milk powders are not completely soluble in water, but a standard of a minimum 85 per cent. solubility is generally accepted for powders intended as infant foods. Provided the insoluble particles present are very small and therefore digestible, no account need be taken of them in considering the infant's requirements of milk solids. Larger particles, whether of coagulated milk protein or of caramelised lactose would, of course, render the powder unsuitable. Chemical deterioration, usually due to excessive moisture content or adverse storage conditions such as excessive heat, results in rancidity of the fats and partial hydrolysis or bacterial putrefaction of the proteins (milk powders are never completely sterile even if free from pathogens). These changes cause the product to become highly irritating to the stomach tissues making the powder quite unfit for use even if the infant's stomach could retain it.

By law all milk powders designed for infant feeding must be fortified with vitamin D, and many proprietary brands contain added iron as well, to bring them nutritionally more into line with the infant's requirements.

For infant feeding, dried milk powders may be usefully divided into full cream, fat modified, humanised and " modified special " powders, and it is under these headings that the various forms will be considered.

(1) *Full cream powders.* Being essentially dehydrated total solids of cow's milk, the full cream dried milk powders when used for infant feeding require the addition of warm water that has previously been boiled (not *boiling* water which tends to cause the fat to separate out), in sufficient amount not only to reconstitute the original liquid, but further to dilute it in accordance with the principles already laid down. Moreover, sugar must always be added in order to secure the necessary proportion of carbohydrate. For practical purposes approximately one drachm of milk powder to one ounce of water (1 to 8) gives a reconstituted whole milk. As a rule, a measure or scoop is supplied with these powders, and is designed to contain more or less the correct quantity of milk solids, the exact volume depending upon the *density* of the powder that the scoop was designed to contain. The usual manner of making up the feeds is based on the second method described for liquid milk. First calculate in fluid ounces the total daily intake of fluid required for the particular child and divide into 5 equal portions. Mix with this number of fluid ounces of boiled water *one less* than this number of scoopfuls of milk powder and a teaspoonful of sugar ; this will give the required feed, thus:

Weight of child, say, 10 lb.

Daily requirement of fluid 2½ × 10 fl. oz. = 25 fl. oz.
Fluid required at each of 5 feeds = 5 fl. oz.

Each feed would therefore be made up as follows:

Boiled water	5 fl. oz.
Milk powder	4 scoopfuls.
Sugar	1 teaspoonful.

The above method is very widely recommended, occasionally with slight and usually insignificant modifications. During the first 3 or 4 weeks of life, however, the final mixture must be somewhat more dilute than this.

Fat modified milk powders. The fat modified milk powders used in infant feeding are three-quarters and half cream. Except that many brands do not require additional sugar, they may be used in exactly the same way as full cream powders. Half cream milk powders are employed mainly in the feeding of weak or sickly infants and during the earlier months in the case of infants who exhibit some intolerance to fats. They are not suitable, however, for prolonged feeding. The three-quarters cream powders were designed for use in the tropics because climatic conditions there make fats less easily tolerated. They are suitable for using throughout the period of artificial feeding.

" *Humanised* " *milk powders.* These powders are modified in such a way that on simple reconstitution with water they yield a fluid approximating in composition more or less closely to human milk. One simple way of producing such a powder is to blend a full cream powder with lactose or milk sugar. More elaborate formulations provide for the breakdown of cow's milk into its three main constituents, protein, carbohydrate and fat, and the reblending them in such proportions as to yield a powder approximating quantitatively very closely indeed to human milk. In preparing infant feeds from these powders no sugar must be added and one measureful of the powder is reconstituted with one fluid ounce of boiled warm water.

Modified special powders. Milk powders modified in various ways are available on the market for use in the treatment of certain illnesses and diseases. For example, powders which on reconstitution yield a fluid containing a rather higher proportion of protein than is present in human milk may be used in the treatment of certain wasting conditions. Powders containing lactic acid are sometimes employed in therapeutics and have certain advantages. They are based upon the fact that milk being a good " buffer " is capable of absorbing considerable amounts of acid without much change in its reaction to litmus. Where the secretion of hydrochloric acid in the stomach falls below normal levels (see section on physiology), most of the acid present is absorbed by the milk, leaving no excess of acid to form the medium in which enzymatic digestion by the stomach normally takes place. The use of lactic acid satisfies the milk-buffer and leaves the small amount of hydrochloric acid secreted in this type of case free to fulfil its proper function of providing an acid medium in which peptic digestion may take place. Other special powders used in feeding of abnormal cases include buttermilk and whey powders, peptonised powders of various formulations where the protein has been partly digested during the process of manufacture, and powders of very low fat content containing additional proteins and carbohydrate to bring the calorific value back to a suitable level for nutritional purposes. In the case of infants allergic to cow's milk, the problem may be tackled in two ways without resorting to the so-called artificial milks. Since the allergy-producing properties usually reside in the albumin-globulin fraction of the protein, this fraction may be more or less completely removed by heat coagulation and a powder of which the protein will be almost entirely casein can be prepared from the remainder. The alternative is to use the milk of some animal other than the cow. Goat's milk is probably most suitable and readily obtained, and is, moreover, available in powder form.

Condensed and Evaporated Milk. In the manufacture of these, whole or skimmed milk is evaporated by means of a greater or less degree of heat, and under reduced pressure to a strength that is usually slightly more than twice that of the original. Preparations from skimmed or separated milk are utterly unsuitable for infant feeding, and are required by law to be labelled accordingly. In popular parlance condensed milk usually refers to a full-cream evaporated milk to which about 43 per cent. of sucrose has been added. Because of their very high sugar content they are not suitable for the feeding of normal infants, though they have their temporary use in the treatment of disease. The unsweetened variety, the one commonly referred to as " evaporated milk ", is eminently suitable for infant feeding. When they are employed for infant feeding, the usual vitamin supplements must be provided. Feeds based on evaporated milks are prepared by simple dilution with water and the addition of sugar as for fresh milk and full cream powders. A suitable formula would be:

Unsweetened evaporated milk . .	¾ fl. oz.	= 35 cal.
Water	1¾ fl. oz.	
Sugar, a teaspoonful or 1 drachm .		= 15 cal.
Total fluid	= 2½ fl. oz.	= 50 cal.

Caseinates. Another milk product which has a useful place in infant feeding is the caseinate of sodium or calcium. Sodium caseinate is a glutinous protein which is not pleasant to take or easy to handle, and it has been largely given up in favour of the calcium salt. Calcium caseinate can be obtained as a dry, powdered protein, and is useful for increasing the protein content of infants' diets in circumstances where this is medically indicated. Being practically free of sodium, calcium caseinate is used to provide the protein in salt-free (*i.e.*, sodium-free) diets necessary for the treatment of certain diseases, and with the addition of suitable amounts of cream, sugar, and minerals a synthetic milk eminently suitable for such cases can be formed.

See Diseases, human; Enzymes; Humanised milks; Milk powder; Nutritive value; Rennet; Soft curd milk.

Refs.: Bacharach; Cronshaw; Kon and Mawson; Richmond; Rogers; Graham (1952), *BJN*, **6**, 207; Waller, 210; Gunther, 215; Smellie, 220; Neale 224; Crosse, 230.

INFECTION. The infection of an animal by pathogenic micro-organisms (or a " disease ") is controlled by many factors of which the most important are: (i) the type of organism; (ii) the number gaining access to the tissues of the animal; (iii) the physiological condition or *virulence* of the organisms at the time of infection; (iv) the physiological condition or state of *resistance* of the animal. *See* Diseases; Immunity; Virulence.

Ref.: Wilson and Miles.

INFERTILITY IN DAIRY CATTLE. *See* Diseases of dairy cattle.

Ref.: Hignett (1952), *JBDFA*, **56**, 5.

INHERITANCE. *See* Breeding.

INHIBITORS. (i) Chemical substances, *e.g.* quinoline derivatives, which prevent the corrosion of metals when plant is treated with acid preparations for descaling or removing the scale or " fur " of calcium salts deposited from hard water.

(ii) In bacteriological media such substances as bile salt, crystal violet, etc. *See* Cleaning; Descaling; Media.

INHIBITORY SUBSTANCES IN MILK. These may be classified as

(i) antibiotics (p. 55);
(ii) drugs (e.g., sulpha drugs);
(iii) quaternary ammonium compounds (p. 879);
(iv) chlorine;
(v) naturally occurring (physiological abnormalities).

For methods of testing *see* Silverman and Kosikowsky (1952) *JMFT* **15**, 120.

The naturally occurring inhibitory substances in raw milk was called *lactenin* by Jones and Simms (1930, *J. Exp. Med.*, **51**, 327) and has been further studied by Auclair and Hirsch (1953, *JDR*, **20**, 45) and Auclair and Berridge (1953, *JDR*, **20**, 370).

See Antibiotics: Chlorine; Disinfection; Germicidal action of milk; Lactenin.

INSECTICIDES. Insecticides are chemical formulations for controlling insect pests. In food-importing countries like Britain, the control of insects attacking growing food crops or infesting stored foods (including cheese, etc.) is a problem of national importance. The control of insects like houseflies and blowflies is also important in the interests of hygiene; there is evidence that blow flies, for example, are important vectors of disease, including poliomyelitis. The control of these pests in dairy premises should therefore be regarded as an essential part of good housekeeping. The study of insect pests and of the methods of their control falls into three main divisions, each of which is a responsibility of the official bodies indicated below. Important research and development is also undertaken by many university departments and industrial organisations:

(A) Pests of medical importance, *e.g.* mosquitoes, tsetse flies, lice, bed-bugs, skin-infesting mites, etc. (Medical Research Council). (B) Pests of agricultural importance, *e.g.* Colorado beetles, aphids, wireworms, etc. (Agricultural Research Council). (C) Stored products and domestic pests, *e.g.* Cacoa moths, clothes moths, grain weevils, cheesemites, houseflies, cockroaches, etc. (Infestation Control Division of the Ministry of Agriculture and Fisheries—control measures; Pest Infestation Laboratory of the Department of Scientific and Industrial Research—research and domestic pests). The dairy technologist is likely to be concerned with (C) only.

Insecticides may be applied as poison baits, dusts, smokes, sprays, and as fumigants. The following are typical:

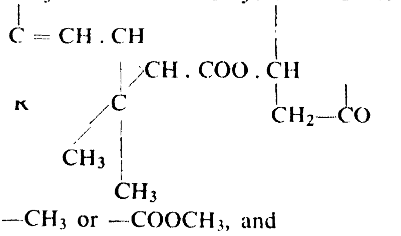
Thallium Sulphate mixed with sugar or jam as the bait, is used as an ant poison. It is left on small trays on the located ant routes. The salt is poisonous to mammals, and precautions must be taken to preclude the contamination of food.

Sodium Fluoride mixed with inert carriers such as talc, is an effective dust against cockroaches and silver fish. This salt is poisonous to mammals, and precautions must be taken to preclude the contamination of food.

Gammexane is the proprietary name for the γ-isomer of hexachlorocyclohexane ($C_6H_6Cl_6$) or benzene hexachloride (abbreviated BHC). It is usually applied as a dust so that insects, particularly larvae, crawling over dusted surfaces absorb lethal doses. It is also dispersed from smoke generators which are ignited like fireworks, shelf, floor and cupboard surfaces, etc., receiving a light fairly uniform insecticidal deposit. Gammexane is particularly effective against houseflies and moth larvae. Gammexane dust formulations often have a persistent musty odour, so that tainting of foods, particularly fatty foods, must be guarded against. The insecticide tends to accumulate in certain organs of animals ingesting contaminated food. The interdepartmental insecticide organisation of the Agricultural Research Council has recommended tentatively that the concentration of the γ-isomer shall not exceed 2·5 parts per million in food.

DDT is an abbreviation for 1 : 1 : 1-trichloro-2 : 2-bis (4-chlorophenyl) ethane ($(p\text{-}C_6H_4Cl)_2CH\,.\,CCl_3$). It is formulated as a dust using inert carriers such as talc and in aqueous suspensions containing up to 20 per cent. pure DDT. Pyrethrin sprays (*see* below) sometimes contain DDT, which has a definite but delayed lethal effect on houseflies, etc., whereas the pyrethrins alone have an immediate but often only temporary " knock-down " effect. On ingestion of DDT-contaminated food, animals tend to accumulate the insecticide in fatty tissues which may lead to damage to the liver, for example. For this reason the contamination of food must be guarded against. The Interdepartmental insecticide organisation of the Agricultural Research Council has tentatively recommended that the concentration of this insecticide shall not exceed 7 parts per million of any foodstuff. DDT has been found superior to repellant-type sprays in maintaining herd milk production, since this has been found to be inversely related to fly abundance (Bruce and Decker, 1947). It has, however, been reported that DDT applied to cows may find its way into the milk (Carter and Mann, 1949). DDT-contaminated hay (7-8 p.p.m.) fed to cows resulted in a concentration of 65 p.p.m. of DDT in butter made from the milk (Smith, Hoskins, and Fullmer, 1948). Such factors as these must be carefully considered before using DDT or similar fat-soluble insecticides (*e.g.* Gammexane) on dairy cattle, or where it may extensively contaminate dairy-cattle feeding stuffs.

Pyrethrins. These are natural insecticides obtained from the flower heads of the Chrysanthemum genus, one of the principal sources being *Chrysanthemum cinerariaefolium.* The insecticide may be used as a powder obtained by grinding the dried flower heads or as a concentrated petroleum extract. The pyrethrins have been shown to be esters of the type



where R may be $—CH_3$ or $—COOCH_3$, and

$R',—CH_2\,.\,CH : CH\,.\,CH : CH_2$ or $—CH_2\,.\,CH : CH\,.\,CH_3$.

The pyrethrins probably represent one of the nearest approaches to the ideal insecticide. They possess extremely useful insecticidal properties against houseflies and moths, but are relatively innocuous to higher animals. They are a common constituent of many commercial sprays available for domestic or factory use. Commercial preparations usually consist of a refined mineral oil solution of the natural pyrethrins, together with DDT, which adds persistent residual and lethal effects to the characteristic " knock-down " effects of the pyrethrins themselves. Substances such as piperonyl butoxide are sometimes added to enhance the effective toxicity of the insecticide. A disadvantage of the pyrethrins is that residual films deteriorate under atmospheric conditions. This may be partly offset by the addition of antioxidants. A synthetic homologue of one of the pyrethrins is now available commercially. It seems possible that the natural products will eventially be superseded by the synthetics which are of comparable toxicity and of superior stability.

Fumigants comprise the volatile or gaseous insecticides which are thus able to penetrate the intergranular spaces of bulked wheat, maize, flour, etc., which are inaccessible to dusts, sprays, or smokes. Typical insecticidal fumigants are hydrogen cyanide (HCN), methyl bromide (CH_3Br), ethylene oxide ($\overline{CH_2.O.CH_2}$), and the aliphatic chlorinated hydrocarbons such as carbon tetrachloride (CCl_4), ethylene dichloride (1 : 2-$C_2H_4Cl_2$), tetrachlorethylene (C_2Cl_4). Hydrogen cyanide and methyl bromide are highly toxic to man, while ethylene oxide forms dangerously inflammable mixtures with air unless mixed with an inert diluent like carbon dioxide. They should only be used, therefore, under expert supervision. The chlorinated hydrocarbons, on the other hand, are liquids at ordinary temperatures, and are relatively safe to handle. They have been used successfully in the small scale fumigation of cereal grains, animal feeding stuffs, etc., by simply sprinkling the fumigant (*e.g.* from a watering-can) over the infested material contained in a suitable bin (*e.g.* large dustbin). The bin is sealed for the period of fumigation and opened for the airing process, which should always follow fumigation (Farrar and Flint, 1942). Dichloroethyl ether and methyl bromide have been used for fumigating mite-infested cheeses, store rooms, etc. (*see* Cheese Mite).

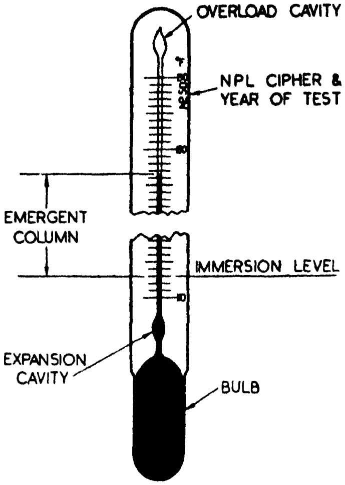
Control Measures—General Remarks. When dealing with insect problems in the dairy industry, great care must be exercised to avoid the contamination of dairy products or livestock. For dealing with flies and infestations of premises, pyrethrin sprays containing DDT are probably the best compromise between safety and effectiveness. Many effective formulations are available commercially, together with instructions for their use. Suitable hand-sprayers are available at most hardware dealers, while one has been designed for hand or compressed air operation (Higgins and Green, 1949). Infestation of stocks of wheat, maize, oats and other animal feeding-stuffs by weevils, etc. may occur on dairy farms. When there is no alternative to continued storage, fumigation is probably the best answer, but technical advice should first be sought. Cheese mites present a problem peculiar to the dairy industry, and require special methods of treatment (*see* Cheese Mite). Useful publications are: Brown, A. W. A., *Insect Control by Chemicals;* Hinton, H. E. and Corbet, A. S., *Common Insect Pests of Stored Food Products*, British Museum (Natural History), 1949. Freeman, J. A. and Turtle, E. E., *The Control of Insects in Flour Mills*, H.M. Stationery Office, 1947. Home Office, *Fumigation with Methyl Bromide—Precautionary Measures*, H.M. Stationery Office, 1947. Home Office, *Fumigation with Ethylene Oxide—Precautionary Measures*, H.M. Stationery Office, 1951. *Fly Control in Dairy Cattle and Dairy Barns*, U.S. Dept. Agric. Leaflet No. 285, 1950.

Refs.: Bruce and Decker (1947), *J. Econ. Entomol.*, **40**, 530-536 (Flies and milk production); Carter and Mann (1949), *J. Econ. Entomol.*, **42**, 708 (DDT in milk); Farrar and Flint (1942), *J. Econ. Entomol.*, **35**, 615 (Fumigation); Higgins and Green (1949), *Annals of Appl. Biol.*, **36**, 383-393 (Sprayers) ; Smith, Hoskins and Fullmer (1948), *J. Econ. Entomol.*, **41**, 759 (DDT in butter).

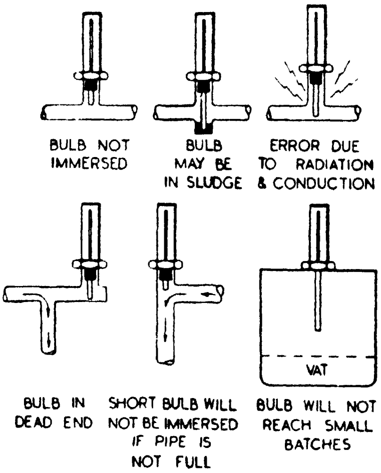
INSPECTION. (i) Of dairy farms. *See* Clean milk production ; Farm advisory work.

(ii) Of incoming milk. *See* Butter ; Cheese ; Grading ; Management of creameries ; National Milk Testing and Advisory Scheme ; Platform testing.

INSTRUMENTATION. The instruments used in the dairy industry today are the result of constant research to find types which will operate under exacting conditions. Whilst a high degree of absolute accuracy, reliability, and speed of response is demanded, it is also necessary that they should be of rugged construction to withstand constant handling during plant cleaning, and be capable of working continuously in a humid atmosphere. That such instruments are available which will fulfil these conditions, if given reasonable care and attention, is a tribute to the instrument designer.



LIQUID IN GLASS THERMOMETER
FIG. In 1.


BULB NOT IMMERSED
BULB MAY BE IN SLUDGE
ERROR DUE TO RADIATION & CONDUCTION
BULB IN DEAD END
SHORT BULB WILL NOT BE IMMERSED IF PIPE IS NOT FULL
VAT
BULB WILL NOT REACH SMALL BATCHES

By courtesy of Negretti and Zambra Ltd.

EXAMPLES OF BAD POSITIONING OF THERMOMETERS
FIG. In 2.

All the benefits of a first-class instrument will be nullified, however, if it is not positioned correctly on the plant. It is essential, for instance, to ensure that any form of thermometer is adequately immersed at all times, and that the liquid should be flowing freely over the bulb (Fig. In 1).

The majority of instruments used in the dairy industry are concerned with the measurement of temperature, and although some of the modern instruments are relatively complicated, the *mercury in glass thermometer* is still the most important. This simple device is the recognised practical standard against which all mechanical and electrical instruments should be periodically checked. Because of its simplicity it is frequently incorrectly used and the readings given by it are not questioned. It must not be thought that every glass thermometer is accurate — indeed many in common use are far from it. Years ago the floating dairy thermometer was practically the only type in use, and it could only be sold at a ridiculously low price. Such thermometers are available today of high quality, but of course at a higher price. The chief defect to be watched for is the slipping of the enclosed scale relative to the tube containing the mercury or spirit.

Every dairy should possess at least one standard thermometer which has been certified by the National Physical Laboratory (N.P.L.). Such a thermometer will have the monogram NP and the year of test engraved on the stem, and will be supplied with a certificate showing the errors to be allowed for at various temperatures. The certificate will also give the conditions under which it was tested and these must be repeated when it is used. Whilst any certified thermometer of the appropriate range may be used, a special type is available known as a dairy test thermometer. It is supplied with a range of 25° to 50° F., 140° to 155° F., or 145° to 170° F., to suit the usual processes. In all cases readings can be made easily to 0·2° F.

If a thermometer is mounted in any form of metal protecting sheath, errors are introduced by the effects of radiation and conduction, and for this reason the N.P.L. will not give a certificate for a thermometer so mounted.

Errors of the order of 1° F. at temperatures in the heat treatment range can be caused if a thermometer which is calibrated for immersion to the reading, is used with only the bulb and part of the stem immersed (Fig. In 2).

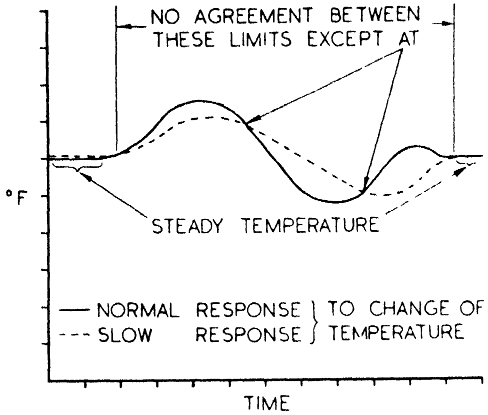
This emergent stem error can be calculated. (*See* " Temperature Measurement ", B.S.I. Code 1041.)

Check or Indicating Thermometers. These are usually mercury in glass thermometers, mounted in a metal sheath attached to the plant. Because of the sheath and the partial immersion, they will not usually give a better accuracy than about ± 0·8° F. Actually, the maximum permissible correction for the issue of an N.P.L. " Class A " certificate for a partially immersed *unmounted* thermometer, divided in single degrees, for a test range of 140° to 212° F., is ± 1·1° F. Due to the comparatively rough handling to which they are subjected, they can become more inaccurate, and should be periodically checked against a standard thermometer.

Common causes of inaccuracy are: (A) Movement of the tube relative to the scale. It is better for the graduations to be engraved on the glass tube; (B) A break in the column of mercury causing the reading to be too high; (C) Trapping of the mercury in the expansion chamber at the top of the tube, causing the reading to be too low.

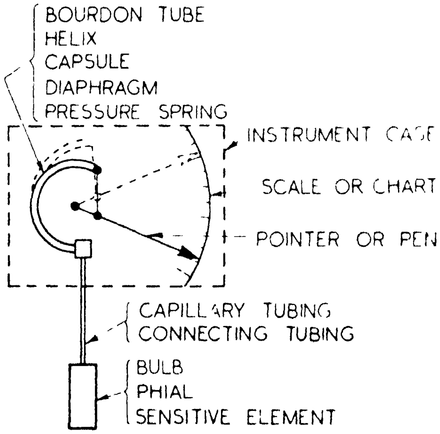
Conditions (B) and (C) can usually be corrected by vigorous swinging of the thermometer with the bulb lowermost, except when the tube has been filled above the mercury with an inert gas. This gas has the effect of preventing breakage of the mercury column, but it is not always effective if the thermometer has received a very sharp jolt. The presence of the gas filling is sometimes indicated by the engraved letter N on the tube or scale. If the break is near the top of the column it is sometimes possible to unite it by very cautious warming of the bulb, so that the trapped gas can escape to above the mercury in the top expansion cavity. If this fails, the thermometer should be returned to the maker for adjustment.

Checking Thermometers. The essential conditions for the checking of thermometers against a standard are as follows: (A) The use of the standard thermometer under the exact conditions specified on the certificate and the application of any necessary corrections; (B) The thermometer being tested must be checked under conditions resembling those on the plant. This applies particularly to the immersion of the bulb and its relative height with respect to the



EFFECT OF THERMOMETRIC LAG WHEN COMPARING THERMOMETERS UNDER CHANGING TEMPERATURE CONDITIONS

Fig. In 3.



THERMAL SYSTEM

Fig. In 4.

By courtesy of Negretti and Zambra Ltd.

indicator or recorder; (C) Both thermometers must be immersed in water which is well stirred and maintained at a steady temperature. A churn of hot water will usually cool slowly enough to permit steady readings.

The object of maintaining a steady temperature is to overcome errors due to the difference in the response or thermometric lag of the two thermometers. It is exceptional for two thermometers to take up a change in temperature in exactly the same time, and it is this fact which accounts for the difference in the readings given by two accurate thermometers when they are attached to a plant where the temperature is varying rapidly.

In general, the bulb of a liquid expansion thermometer has its size governed by the range of the instrument. The fewer the degrees on the scale the larger the bulb and the slower the response. Thus, a thermometer having only a few degrees each side of the working temperature would have such a large bulb that the instrument would fail to show changes of temperature until some considerable time after they had occurred. With an oscillating temperature the thermometer would be very misleading, as it would indicate that conditions were steady (Fig. In 3).

When satisfied by repeated readings that an instrument is reading inaccurately, the necessary adjustment should only be made by a responsible person. In the case of an instrument not having any convenient means for adjustment, a label should be attached showing the error. To avoid confusion it is best if the information is stated in the form " at 161° F. add (or subtract) 0·5 F. ".

It is very unusual for a thermometer of any type to read high on one day and low the next. If this effect is noted, the method of testing should be suspected rather than the instrument.

It is possible to check a thermometer whilst it is attached to the plant, provided that a standard of known accuracy can be inserted in the same flow of milk which is surrounding the thermometer and that temperature conditions can be maintained steady for a reasonable time.

Temperature Measuring Systems. Whilst the mercury in glass thermometer is the simplest instrument which can be used to measure temperature accurately, it cannot easily be arranged to record or control. For this purpose mechanical, and to a limited extent, electrical instruments are used.

The most commonly used types are those employing either mercury expansion or the vapour pressure of volatile liquids as the operating force. In both types the instrument is made of metal with a bulb placed at the point of temperature measurement, connected to a Bourdon tube by small bore tubing suitably protected against mechanical damage (Fig. In 4).

The Bourdon tube is a flattened metal tube with one end closed and formed so that when pressure is applied internally, the shape of the tube is altered. They are made in many different ways, from the simple C type commonly used in pressure gauges, to those where the tube is made into a spiral or helix. Expansion of the mercury or an increase in the vapour pressure resulting from a rise in temperature of the bulb causes the closed end of the tube to move. This small movement is usually magnified by a lever system to which a pointer or pen arm is attached and arranged to traverse a graduated scale.

Flexible capillary tubing is used so that the bulb may easily be removed for cleaning, and because of the constant bending to which the tube is subjected it ultimately breaks. Since the whole system is a closed one under pressure, the instrument is then rendered useless.

Much can be done to prolong the life of the instrument if care is exercised in handling the tubing, and it is a good plan to provide a definite resting place for the bulb when the plant is dismantled for cleaning rather than let it lie around on the floor.

Many modern plants dispense with a flexible capillary tubing and use in its place a rigid tube with the bulb attached. When the plant is dismantled for cleaning, the pipe lines are removed from the bulb, leaving the latter attached to the instrument panel. This arrangement cannot, as a rule, be applied to old plants.

A development of the mercury in steel system is the " Fast " bulb thermometer which was specially designed to provide a robust instrument with a very small thermometric lag. The bulb is made from stainless steel and the place of the usual mercury filling is taken by a hollow core of a steel having a low coefficient of expansion. A thin film of mercury separates the two parts of the bulb, but the sole purpose of the mercury is to act as a transmitting medium to the Bourdon tube.

A rise in temperature will cause the outer casing of the bulb to expand, and since the core will not expand, the space available for the mercury will be increased. This space will be filled with mercury from the Bourdon tube which will, therefore, operate in the reverse manner from the usual mercury in steel instrument.

The quick response of the bulb to a change in temperature is due to the large surface area in contact with the liquid and the low heat capacity of the bulb.

It should be noted that a break in the system with the resulting fall in the internal pressure will cause the pen or pointer of the thermometer to read too high instead of too low, as is usually the case.

Recording Thermometers. These are of the usual circular chart type, but should have the temperature range selected so that each degree Fahrenheit is equal to not less than $\frac{1}{16}$ in. at the average working temperature.

Bulbs should be made from stainless steel where they are in contact with the product, and the instrument must be capable of withstanding the effect of the bulb being sterilised with steam. Where it is necessary to record over a wide range of temperature, for instance in the processing of some ice cream mixes, the $\frac{1}{16}$ in. per degree cannot be maintained because the pen travel of the usual recorder is only about 4 in. It is undesirable to have the working temperature near the centre of the chart where the time lines are very cramped, and for this reason it is sound practice to arrange for the lower temperatures to be on the outside of the chart when recorders are fitted to cold stores.

Recording instruments cannot be made watertight because of the need to open the door for the purpose of changing the chart, etc. Most modern instruments are arranged for the door to seat on a rubber gasket, and it should be made a strict rule that the door is not left open at any time.

The instrument should be positioned so that it is not subjected to splashing, and with due regard to the convenience of reading by the plant operator.

Charts are usually rotated by a synchronous motor, but where recorders are situated in isolated positions it is often more convenient to use spring driven clocks. Because of the time factor involved in many milk processes, it is necessary that the time interval at the working temperature should be read easily to a few minutes. This will mean a chart rotating once in 12 hr., but for cold stores and similar positions a daily, or even weekly rotation, will be sufficient.

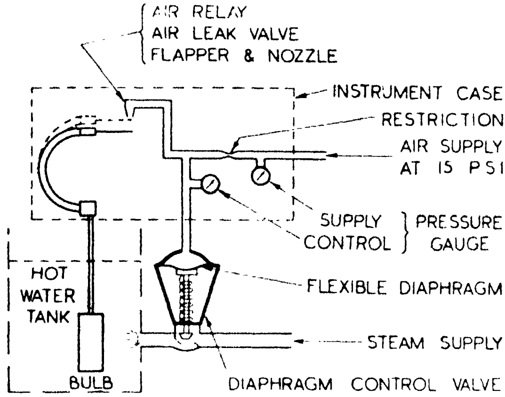
Temperature Controllers. Because of the need to work closely to set temperatures in many dairy processes, these instruments are used extensively today. An absolute necessity for H.T.-S.T. pasteurising, their use on simpler tasks such as bottle washing is rapidly extending.

A temperature controller has two functions to perform ; to measure the temperature, and to operate some arrangement—usually a steam valve—which will correct any tendency of the temperature to deviate from the desired reading.

In the simplest type the expansion of a metal, liquid or gas is used for both purposes, but if, for instance, extra friction arises in the packing gland of the valve, the power to overcome the friction must be derived from a further change of temperature. Thus a temperature which was originally controlled to ± 2° F. may fluctuate 5° F. or more.

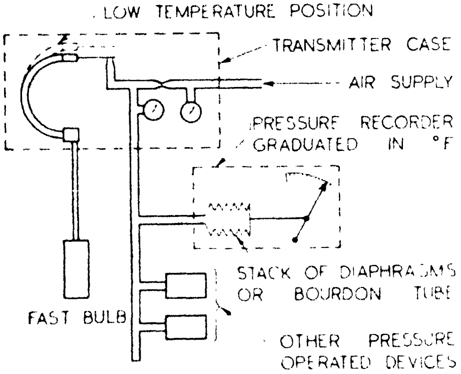
Since they are simple, self-contained and relatively inexpensive, they are used where very close control is not considered necessary.

For accurate control it is necessary to employ an external source of power to operate valves and this is usually compressed air at a pressure of about 20 p.s.i. The temperature is measured by systems of the type used for temperature recorders with the addition of a very small air valve requiring only slight power to operate.



PRINCIPLE OF AIR OPERATED TEMPERATURE CONTROLLER

Fig. In 5.


LOW TEMPERATURE POSITION
TRANSMITTER CASE
AIR SUPPLY
PRESSURE RECORDER GRADUATED IN °F
STACK OF DIAPHRAGMS OR BOURDON TUBE
FAST BULB
OTHER PRESSURE OPERATED DEVICES

By courtesy of Negretti and Zambra Ltd.

PRINCIPLE OF AIR TRANSMISSION

Fig. In 6.

It must be appreciated that all controllers are error operated, and therefore cannot commence to correct a temperature until it has deviated from the normal. The speed with which a deviation is corrected and the amount of the deviation from the set temperature depend upon the type of controller employed and the characteristics of the plant. A controller must be matched to the plant, and if extensive alterations are made to the plant, it may be necessary to employ a different method of control.

The proportional type of temperature controller is the one most commonly used, and operates as follows :

Compressed air at about 20 p.s.i. is used to operate a diaphragm valve on the steam line. If the full pressure is applied to the flexible diaphragm of the valve it will close, and when the air is released the valve will open. A valve working in this manner is sometimes known as " direct acting ", but if the applied air pressure is arranged to open the valve it is known as " reverse acting ". An alternative, and perhaps more descriptive method of describing the action of the valve is to refer to the effect of the air pressure in which case the " direct acting " is known as " opening with air failure ". It is customary to arrange for the valve to travel to the safest position in the event of air failure, but it is essential that the action of the valve is matched to the instrument.

The pressure of the air applied to the diaphragm valve is controlled in the instrument by the operation of an air leak valve or similar device of light weight. This leak device is caused to open or close by the action of the Bourdon tube in accordance with temperature changes.

In order that the air may leak away when the valve is open, at a faster rate than it can be supplied, a restriction is incorporated in the air line.

When applied to a heating process, a fall in the temperature will be detected by the bulb of the controller, which will cause the air leak valve to open. This will allow air to leak away and the diaphragm-operated steam valve will open to admit more steam. When, as a result of this, the temperature rises, the air leak valve will be caused to close, and as the air pressure builds up in the diaphragm of the steam valve, that will also close. This cycle is repeated continuously, but in actual practice the instrument would be adjusted to the plant so that the diaphragm valve would take up a mean position to pass sufficient steam to maintain a steady temperature.

This type of temperature controller is quite satisfactory on those plants where the temperature of the milk is kept constant indirectly by controlling the hot water used for heating it, providing the load on the plant is reasonably constant. Occasional manual resetting of the controller will be necessary during a run to allow for slight alterations of the load, but this will only occupy a very small part of the operator's time on a plant which is run under steady conditions. In all control problems it is desirable to eliminate as many variables as possible, and in the case of a milk plant this means steady milk and steady hot water flow, constant steam pressure, and the avoidance of extreme changes of temperature of the incoming raw milk.

It is possible to control from the final hot milk temperature, but only at the expense of complicated and therefore more costly instruments. This is because of " plant lag ", which may be defined as the time taken for a change in the heat input to influence the temperature of the final hot milk. In the H.T.-S.T. process, this lag is increased by the holding period of 15 sec. which means that from the time that a temperature controller detects a drop in temperature of the final hot milk, until the temperature starts a rise again as a result of the admission of more heat to the plant, 20 to 30 sec. will have elapsed. During this time the diaphragm valve will have remained open so that the milk will be overheated, and when this hotter milk makes contact with the controller bulb the instrument will close the diaphragm steam valve and cause the milk to be underheated. A continuous cycle of over and under heating will therefore result.

The solution of this problem is found by the use of two temperature controllers of a type capable of controlling accurately despite changes of load. One instrument controls the temperature of the heating water, and the other with its bulb in the final hot milk, alters automatically the setting of the hot water controller in the same manner that a skilled operator would. The hot milk controller is usually combined with the hot milk recorder, together with the devices necessary for the working of the flow diversion valve.

Pasteurisers of the rotary type also require special types of temperature controllers due to the large temperature difference between the steam used as a heating medium and the milk. The small heat capacity of the plant also increases the difficulty of control because there is nothing to even out small temperature variations. For the same reason it is essential that the flow of milk is constant and the steam pressure must be controlled.

At the other end of the scale is the batch pasteuriser where the milk has to be maintained at a constant temperature for 30 min. Heating is normally by hot water without much circulation of either the heating medium or the milk, resulting in a slow rate of heat transfer. Temperature controllers are available for this type of plant, but in order to keep the price of the instrument within reasonable limits they are usually of a relatively simple type which will require some attention from the operator.

Temperature control can be applied to almost any process in the dairy industry, but it is not possible to use any one type for all of them. It must be emphasised that every controller must be matched to the plant, and from this it follows that any extensive alteration to the layout or duty of a plant will mean that the controller will need to be adjusted to suit the new conditions.

The type and size of the diaphragm control valve will greatly influence the accuracy of the control obtained. In the past there has been a tendency to make use of any available valve, the characteristics of which might bear no relation to those of the controller with which it is expected to operate. Best control is usually obtained with a diaphragm valve operating about three-quarters open under normal conditions.

Too large a valve will mean that a fractional movement of the valve spindle will cause too large a change in temperature, whilst too small a valve may not be able to pass sufficient of the heating or cooling medium to take care of abnormal conditions.

The positioning of the bulb of the controller is also of the utmost importance. Plant layout will often determine this, but if possible the bulb should be placed where the effect of a change in temperature can be detected quickly. Conversely, if the position of the bulb of a controller is altered from the original position, it is more than likely that the quality of the control obtained will deteriorate.

Instruments for H.T.-S.T. Plant. The temperature recorders and controllers previously described are used for this process, but the call for still faster response and accuracy of measurement of the temperature at which underheated milk is diverted has resulted in the introduction of a method of control generally known as *air transmission* (Figs. In 5 and 6).

The temperature lag of a thermal system is related to the size and therefore the heat capacity of the bulb. Reducing the size of the bulb reduces the lag, but it also means that less power is available to move the pen across the recorder chart. The friction of the pen on the chart is sufficient to interfere with accuracy, and the further operation of any device to divert underheated milk reliably at a set temperature becomes impossible without an external source of power. The arrangement is really a development of the air relay method used for controllers, but with the diaphragm valve replaced by an air pressure recorder of normal construction. The very small movement of the Bourdon tube of the thermal system resulting from the use of a small bulb is used to operate an air relay which in turn controls the air pressure applied to the pressure recorder. This instrument carries a chart marked in degrees Fahrenheit of the usual type. A temperature change from 130° to 190° F. is converted to a pressure change from 3 to 15 p.s.i. and makes available plenty of power to operate switches, etc. Because of this conversion the instrument is sometimes referred to as a *temperature converter*. Any reasonable number of air-operated devices may be connected into the same pressure line—if necessary at a distance—and advantage is taken of this feature to work a relay to release air from the flow diversion valve. This relay takes the place of the electric contacts which are often fitted to temperature recorders for the same purpose, but it has the advantage that no interference takes place with the temperature recording.

The air transmission system, when applied to the H.T.-S.T. process, is mounted together with the temperature controller and cold milk recorder, upon a panel so that all the instruments and switch gear for the plant are grouped.

Electricity is replaced by compressed air for the working of all switches, etc., and for this reason the panel is often known as the *fully pneumatic type*.

Attached to the panel and connected to the milk lines coming from the heater is a special valve known as a *flow diversion valve* (F.D.V.). The purpose of this valve is to divert back to the raw milk tank any milk which has not been heated to the required temperature. In the fully pneumatic panel the F.D.V. is operated by a diaphragm similar to that used in the temperature controller valve. An air relay known as a *flow diversion controller* is worked by the same air pressure which operates the recorder and incorporates a special snap action metal diaphragm which releases the air from the diaphragm attached to the F.D.V. This permits the F.D.V. to operate with a quick action under the influence of a powerful spring. The temperature at which diversion takes place is adjustable on the diversion controller without reference to the reading on the temperature recorder.

The recorder showing the temperature of the hot milk is fitted with two further pens. One of these marks a continuous line towards the outside edge of the chart when the door of the instrument is closed, but the trace is broken when the door is opened. A permanent record is therefore obtained of the time at which the door was opened.

The other pen also draws a continuous line, but the position of the trace is determined by the operation of the F.D.V., both during normal running and during the cleaning of the plant. It is thus possible to see from this chart the temperature at which the milk has been processed, and that the various safeguarding arrangements have been functioning correctly.

Besides the fully pneumatic type of control panel just described, the electrical equivalent of it is still used extensively. In this type the operation of the F.D.V. is effected by carefully adjusted electric contacts worked by the hot milk recorder. In one make the contacts are so arranged that on a falling temperature the contact is made accurately despite the fact that the recorder pen may be bearing hard upon the chart and thereby causing a delay in recording the fall in temperature.

The bulb of the temperature recorder is in this type usually placed at the inlet to the holder, as this will overcome the trouble due to the thermometric lag. As underheated milk will be detected soon after it enters the holder, there will be several seconds before the F.D.V. need operate to ensure that the milk is diverted before it can pass forward. However, upon the milk regaining the correct temperature the F.D.V. could return to the forward flow position whilst there is still some underheated milk in the holder. To guard against this, a time delay device is incorporated in the electrical circuit to prevent forward flow until after about 30 sec. circulation of milk at above the diversion temperature.

The F.D.V. on this type of plant is caused to divert by the withdrawal of a pin by a solenoid which permits the operation of the valve by a weight. To obtain forward flow after the correct temperature has been reached again the valve must be reset by hand. This can only be done after the 30 sec. interval which is indicated by a signal lamp.

The hot milk recorder on this type of plant also has an extra pen to record when the F.D.V. has worked.

Other types of F.D.V. are in use where compressed air is used to work the valve by means of a diaphragm, but where the admission or exhaustion of air in the diaphragm is controlled by a solenoid. This solenoid is energised by a contact made in the hot milk recorder which in this case is referred to as a *safety thermal limit recorder.*

From the foregoing brief descriptions it will be seen that the control panels of a modern H.T.-S.T. plant represent the highest peak of instrumentation in the dairy industry. That their use is demanded by law is secondary to the fact that H.T.-S.T. pasteurising plants cannot be operated efficiently without the most modern types of instruments. Proof of this statement is soon forthcoming when instruments break down, as indeed must any mechanical or electrical instrument when subjected to the conditions inseparable from milk processing rooms. In view of this it is surprising that more care and attention is not paid to instruments in the dairy, and the carrying of complete spare instruments which can be installed quickly on site with the minimum of disturbance is almost unheard of.

Many dairy plant manufacturers have a very efficient service department, but with the best will in the world they cannot be on site immediately a breakdown occurs. For this reason it is desirable that at least one man at each plant should be made responsible for the maintenance of instruments and should be encouraged to take an interest in their efficient functioning. This practice is becoming widespread in many other industries where the use of instruments is not enforced by law, but where their worth as an aid to efficient functioning of a plant is now fully recognised.

Care and Maintenance of Dairy Instruments. Modern instruments will give years of trouble-free service if they are only given reasonable care and attention. The moving parts are of necessity rather delicate and should not be interfered with. Since their movement is small, they do not in general require lubricating; in fact, the use of ordinary lubricating oil is likely to do more harm than good. All parts should be kept clean and free from moisture. Electrical connections must be maintained in good condition, and precautions taken to ensure that water does not gain entry to switches, etc.

Air-operated instruments must have a supply of clean dry air. The number of instruments of this type in use in any one dairy does not perhaps justify the elaborate cleaning and drying arrangements in common use in, say, the petroleum industry, but much can be done on a simpler scale to produce reasonably clean and dry air.

Air compressors are generally too small, or existing compressors, originally large enough, have additional instruments attached to the circuit. This results in the air reaching the instruments at a temperature considerably in excess of the air surrounding them.

The resulting drop in temperature of the compressed air causes it to deposit moisture on the working parts of the instruments.

Fabric filters will not exclude water and oil from the air which should have been deposited in the trap always supplied with air-operated instruments. This trap should be fitted at the lowest and coolest point in the circuit, and should be drained at least daily.

The inlet air to the compressor should be taken from a cool and dry place. It is often an advantage to use a large bore pipe leading to the outside air, but arranged so that rain cannot enter. Use only the oil recommended by the makers of the compressor, and do not over oil.

In a surprisingly large number of cases, troubles which are thought to be due to faulty operation of the instruments have been found to be caused by the condition of the plant. Loss of steam pressure is frequently the cause of a complaint about a temperature controller. The instrument can only open the steam valve to the full extent upon a fall in temperature, but if the steam pressure has fallen too low it may not have sufficient heat to restore the milk temperature. Alteration of the flow of the circulating hot water or of the milk due to incorrect assembly of the plant after cleaning, is another cause of trouble for which the instruments are blamed.

Air-operated instruments are fitted with gauges to show that air at the correct pressure is reaching the instruments. Controllers usually have a further gauge to show the pressure of the air on the diaphragm of the control valve. As the movement of the valve spindle is roughly proportional to the applied air pressure, the gauge will indicate the approximate opening of the valve.

Observation of this gauge will often provide the clue to the cause of the trouble. If with a given throughput the gauge normally reads, say, 8 p.s.i., and is now reading only 4 p.s.i., something in the conditions external to the controller must have altered. A properly adjusted temperature controller should have the gauge on the diaphragm valve line indicating a slight movement of the pointer showing that the control valve is continually adjusting the heat input to the plant.

It should be remembered that unless the instruments have been interfered with, there is little to cause them to go wrong. They are not constantly dismantled as is the plant, and the cause of trouble is nearly always due to external sources. An exception is a recording thermometer where it is necessary to open the door for the purpose of changing the chart and inking the pen. This should only be done by a competent official, and the case should be kept locked at all other times.

When instrument trouble is suspected, first check up the state of the plant and see that all services such as steam, water, compressed air and electric supply are in order before interfering with the instruments. Bear in mind that if the instruments have been operating satisfactorily it is most unlikely that settings will have altered without interference.

Generally it is safer to leave the instrument alone and replace it with a spare, but if circumstances demand that something be attempted, proceed with caution.

Follow the maker's instruction and, when making any adjustment, do one thing at a time and pause to note the effect of the alteration. If no improvement results, replace that adjustment to the original setting before trying something else.

Instrument service engineers often find that everything movable on an instrument has been tampered with, resulting in the complete upset of all adjustments.

Many of these can be satisfactorily corrected only at the maker's works, where special apparatus is available.

If a thermal system has a broken capillary tube or fails to respond to a change of temperature of the bulb, nothing can be done on site to effect a repair. The instrument must accordingly be returned to the supplier, and if the damage is due to accidental breakage, precautions should be taken to avoid a repetition of the trouble. It is often possible to arrange capillary tubing so that it is less exposed when the plant is taken apart for cleaning. Where the tubing can be attached to a part of the plant which is not moved, it should be neatly clipped well out of the way of the operators.

When returning instruments for repair it is a good idea to include in the case a note stating briefly the reason for the return of the instrument. This will avoid much time being wasted in searching for a fault, and will result in a lower repair charge and a quicker return of the instrument. Another cause of delay in dealing with a repair is the frequent omission of any information concerning the sender of the instrument.

When ordering spares it is very desirable that the instrument number is quoted, as this will enable the supplier to ensure that the correct spare for that particular instrument is supplied. Minor alterations are continually being made either as a result of an improvement in design or because of the difficulty of obtaining certain materials.

Guide to Locating and Correcting Instrument Faults. It is assumed that the instruments have been working well up to the time of the fault developing.

Mercury in glass thermometer.

Reads too high or too low.	Broken mercury column. *See* " Check or Indicating Thermometers ".
Does not respond to a change in temperature.	The bulb may be broken inside the tailpiece.

Thermal systems in general.	
Does not respond to a change in temperature.	Leak or break in the system. Return to makers for repair.
Temperature recorders.	
Reads inaccurately.	Wrong chart. Bent pen arm. Carefully straighten and correct any remaining error by the zero adjustment.
Chart not rotating.	Chart not properly fixed. Clock not working.
Recording in steps.	Too much friction between pen and chart. Can be caused by damp or buckled chart. Adjust pen pressure to the minimum necessary to give a clear trace.
Trace too thick.	Clean pen in methylated spirit. Temperature may be fluctuating rapidly due to controller fault.
Slow in responding to a change in temperature.	Friction between pen and chart. Bulb may not be fully immersed or screened by goods if in a cold store.
Temperature controllers.	
Erratic control.	Check that all services are sound, and plant in correct condition. Dirty air may cause the air relay to stick. May often be temporarily corrected by rapid movement of the setting pointer. See that all air lines are sound at the joints.
Temperature cannot be maintained.	Check steam pressure at a point near the control valve. *See* that steam traps, if used, are functioning, and that load of the plant has not increased.
Temperature cannot be kept down.	See that any by-pass valves are closed. Steam pressure may be excessive. Diaphragm valve seat may be worn or prevented from closing properly. Check air line for leaks.
Diaphragm valve fails to move when setting pointer is operated.	Thermal system may be broken. It is usually possible to see movement of the levers attached to the Bourdon tube when the temperature of the bulb is altered. Air lines may be choked, leaking or broken.

Ref. : Benwell (1952), *JSDT*, **5**, 190.

INSTRUMENTS, LABORATORY.

Ref. : Miller (ed.) (1954), *The Instrument Manual*, London ; Elliott and Dickson (1951), *Laboratory Instruments*, London.

INSULATION. The protection of a material from (i) heat transfer ; (ii) electrical potential. For the first purpose cork 2 or 4 in. thick is commonly used in dairying. Aerated rubber and glass and aluminium foil are also used.

INTERNATIONAL DAIRY FEDERATION

Ref. : Mork (1953), *DSA*, **15**, 427.

INTERVAL BETWEEN MILKINGS. *See* Collin's rule ; Composition, factor affecting.

INTESTINAL DISTURBANCES. *See* Diarrhoea ; Diseases Food poisoning.

INTOXICATION. The poisoning of an animal by chemical substances which interfere with the normal behaviour of the animal or the normal functioning of the tissues.

A common form is intestinal toxication by putrefactive bacteria, especially of the *Clostridium* (anaerobic spore-former) type. The drinking of cultures of lactic acid bacteria, especially the high acid-producing types such as *L. bulgaricus*, in milk is found by many sufferers of this complaint to be of great benefit. *See* Acidophilus milk; Food poisoning; Yoghurt.

IODINE. An element essential to animal life and found in small amounts in milk. It is essential for the synthesis of *thyroxin* (p. 1033), the hormone synthesised by the thyroid gland. *See* Hormones ; Milk secretion.

IODINE IN RATION. As iodine is a necessary constituent of thyroxin it is essential to have a ration adequate in this element. The use of iodo-casein has been developed recently for this purpose. *See* Feeding ; Halogenated casein ; Hormones ; Iodine ; Milk secretion.

Refs. : Blaxter (1946), *JAS*, **36,** 117 ; Matthews *et al.* (1939), *JDR*, **10,** 395 (iodine in ration and milk).

ION. An ion is a charged atom or radicle.

ION EXCHANGERS. A general name for water treatment plants such as the zeolite type. These depend on the exchange of ions, especially of sodium for calcium and magnesium, in water by means of the sodium salts of certain compounds which readily release sodium and take in place calcium and magnesium. *See* Water.

IRAN.

Refs. : Adle (1949), *IDC*, 4, 609; Oldham (1952), *D*, **69,** 465.

IRELAND. *See* Eire.

IRELAND, NORTHERN, DAIRYING IN. In Northern Ireland, conditions in the dairying industry differ materially from those prevailing in Great Britain. This can be appreciated as it is a community of small holders ; approximately 75 per cent. of the farms are 30 acres and less, and only about 11 per cent. are over 50 acres. The average number of cows per head is about 8, and in nearly half the total herds the average number is 4.

In 1924, there was a total of 270,910 dairy cattle, and at the outbreak of the Second World War this number showed little change at 269,689. In June, 1950, the figure was 363,240, an increase of about 34 per cent. during the post-war decade.

In 1925, the average yield per cow was estimated at 407 gal. per annum ; there was a gradual drop, even before the war, and in 1942 the estimate was 328 gal. Since then the tendency has been upwards and the 1949 estimate was 403 gal. A number of factors were responsible for the decrease in the pre-war period. In the late twenties and early thirties the price paid for manufacturing milk was extremely low ; this, together with the cattle subsidy of 5s. per live cwt., induced farmers to go over to beef types—the incentive was to store raising and not milk production. No attempt was made to increase milk production by the feeding of concentrates—the vast majority of the cows calved during March to May, and milk was, in the main, produced from an always plentiful supply of summer grass. In winter there was a rapid fall in production. For instance, the monthly intake at a group of creameries in 1924 was: January 15,131 gal., July 80,992 gal. Most of the principal milk and beef breeds are represented, but the predominant ones are the Shorthorn and cross-bred Shorthorn. Although the passing of legislation in 1934 made possible an increase in the price of manufacturing milk, the beef trend continued. The outbreak of hostilities in 1939 changed the picture, and since then there has been a tendency to go over to the dairy breeds. This is made clear from the following table which shows the number of licensed bulls of the principal breeds in 1939 and 1948:

	Shorthorn	*Friesian*	*Aberdeen Angus*	*Galloway*	*Ayrshire*	*Jersey*	*Hereford*
1939	3968	60	775	284	205	38	12
1948	3309	777	390	93	456	33	288

Shorthorn numbers, with special emphasis on the milking strains, have been maintained. The dairy breeds, Friesian and Ayrshire, have become remarkably popular at the expense of the beef breeds. Although under the Live Stock Improvement and Artificial Insemination Schemes emphasis is being laid on milking qualities, every effort is made to ensure that milk is not being obtained at the cost of a calf unsuitable for beef production.

In pre-war years most (about 25 million gal. per year) of the milk outside that produced in the vicinity of densely populated areas was used for the manufacture of butter and cream. Supplies were separated at auxiliary and central creameries and manufactured into butter at the latter. There was also a substantial and remunerative trade in pasteurised thick cream with London and the English Midlands. The separated milk was normally returned to the supplier, and was fed to calves, pigs and poultry. During the summer there was a substantial surplus of butter for export and strenuous efforts were made by the Ministry of Agriculture to improve quality by a system of surprise butter inspections. This included a graduating system carried out by a joint panel of trade and Ministry inspectors.

In the early thirties, in addition to creamery butter, it was estimated that some 140,000 cwt. was made on farms; most of this was consumed locally. It is interesting to note that only in rare instances was a separator used; the custom was to allow the whole milk to ripen naturally before churning. The valuable by-product—buttermilk—was partly consumed on the farms by the family and partly fed to pigs and calves. There was always a substantial local market in the urban areas direct to consumers, bakeries and restaurants. The farmer brought it to these centres in small barrels and wooden churns; this fresh buttermilk trade was a typical feature of Northern Ireland.

Up to 1927 the work of supervising cowsheds and dairies was vested in the local authority, who was responsible to the Ministry of Home Affairs under the Cowsheds and Dairies (Ireland) Order 1908. The first legislation dealing with liquid milk was passed by the Northern Ireland Parliament in 1927 in the form of the Sale of Milk Act (N.I.). It provided for the production and sale of Grade A (Tuberculin Tested) milk, which was approximately equivalent to the grade Certified in Great Britain. The licensing authority was the Ministry of Home Affairs, but officers of the Ministry of Agriculture were responsible for day-to-day supervision. This legislation set a high standard, and although the response was poor, it made both producers and consumers alike conscious of the advantages of a clean, safe milk supply. It laid the foundation for future progress which came with the passing in 1934 of the Milk and Milk Products Act, under which the Ministry of Agriculture became the licensing authority. The passing of this Act, which aimed at the complete reorganisation of the industry and improvement of both liquid and manufacturing milk, constituted a major step. In order to appreciate the problem which the Ministry sought to solve, it is necessary to understand one important difference between the position here and that obtaining in England. When the English Milk Marketing Scheme was launched, approximately 70 per cent. of the milk found an outlet in the liquid market, and only 30 per cent. had to be converted to low category products. In Northern Ireland the position was the exact reverse, and a pooling system, as operated in England, would have been completely unworkable. The very high proportion of manufacturing milk produced on cheap summer grass would have lowered the general pool price to such an extent that it would have been unfair to producers of liquid milk who had to maintain a level production at all times. The problem was approached by separating the market into liquid and manufacturing on the basis of hygienic quality.

The Ministry of Agriculture, although responsible for administration and technical control of the scheme, was not responsible for price fixing, this rested with a Joint Milk Council, consisting of representatives of producers, distributors, consumers and Ministry of Agriculture. A variable levy was imposed on each grade of milk when sold on the liquid market; those who had to sell for manufacture were assured a minimum average price, together with a bonus according to the grade for which a licence was held. In order to meet the bonus payments, levies were imposed on the sales of milk on the liquid market, these went into a Milk Fund, together with licence fees, levies on the sales of butter and margarine and Exchequer contributions. By this arrangement a bonus of 2d. a gal. was paid on Grades A and B and 1d. on Grade C.

To refer to the 1934 Act, it provided for the licensing of three grades of milk for the liquid market, viz. A, B and C; producers who catered for the manufacturing market only did not require to be licensed. Provision was also made for the pasteurisation of grades B and C. The general requirements and bacteriological standards laid down for the grades were:

	A	*B*	*C*
Herd	Double Intradermal Tuberculin Test every six months	Clinical Examination every six months	
Equipment and facilities	Facilities for sterilising by steam, cooling and storage of milk	As A	Facilities for washing and scalding
Bacteriological standards	Plate count not to exceed 100,000 and coliform organisms absent in 1/100 ml.	Plate count not exceeding 300,000 and coliform organisms absent in 1/100 ml.	Methylene Blue Reductase Test for 4 hours
	Bottled on Farm. Caps coloured green	Bottled on Farm, or distributor's premises. Caps coloured brown	Sold loose or bottled. Caps coloured red

The responsibility for supervising the health of herds, inspection of premises, methods of production, the bacteriological and chemical analysis of milk samples and advising on special problems, is in the hands of a full-time staff of Veterinary and Milk Inspectors and members of the Research Divisions of the Ministry of Agriculture.

The outbreak of war brought about a great change in the market for milk—previously the liquid market was confined to Belfast and the urban areas. Various factors were responsible for a marked increase in the demand for milk, foremost amongst these were the National Milk in School Schemes, the presence of very considerable numbers of troops in training, higher wages, and the acute shortage of other foods. Sales for human consumption gradually rose from some 15 million gal. in 1939-40, to over 41 million gal. in 1949-50. In addition, there developed a substantial trade in the export of liquid milk to Great Britain—this rose from almost 1 million gal. in 1940-41, to over 3 millions in 1949-50.

In 1940, the Ministry of Agriculture (on behalf of the Ministry of Food) became the purchaser of all milk produced, and when milk became a priority food there was a substantial all round increase in price. This increase made it possible to fix a uniform price regardless of whether the milk was intended for liquid or manufacture.

In 1942, a milk concentration scheme was brought in, some of the smaller creameries were closed, and producers were directed to send their supplies to one of 30 grading centres. Features of the scheme were the concentration of deliveries from producers into a small number of large receiving centres, and the replacement of the existing price arrangement by one based on hygienic quality. Three categories of milk to cover all grades were established, viz. liquid, manufacturing and reject. To segregate intake, an intensive platform grading scheme was used. Each individual churn of milk was examined by a full-time grading staff—visual examination, taste and smell, were supplemented by a short resazurin test when there was any doubt about the quality of a particular consignment. Supplies which came up to liquid standard were paid for at a flat rate, which varied from month to month; an additional bonus of 4d. was payable to Grade A and 1½d. to Grade B producers. Milk graded as manufacturing was paid a price approximately half that of liquid, and milk rejected was returned to the farmer. In addition to the categories enumerated above, there was a further one—salvage—this applied to milk which was below the legal standards of 3 per cent. butterfat and 8·5 per cent. S.N.F. This class received a flat rate of 6d. per gal. irrespective of whether it was genuine or adulterated. While on the question of chemical quality, the general impression is that there has been no serious decline over the area, although some particular herds show low results.

The remarkable success of the grading system is demonstrated by the very rapid improvement in the general quality of supplies—in 1943-44 6½ per cent. was placed in the manufacturing category, where, in 1949-50, the figure was approximately 1½ per cent. When a supplier showed a bad record in downgrading, the Ministry Advisory Officers visited the farm, gave advice on methods of production, and took samples for further analysis. If a farm visit and sample results showed that the producer was not making an honest attempt to comply with the terms of his particular licence, there was down-grading or possible revocation.

A similar approach was made when deficiencies in butterfat and solids-not-fat were encountered. If an appeal to the cow test showed deliberate adulteration the Food and Drugs Authority was called in.

The concentration scheme of 1942 made possible another important development—the introduction of a flat transport rate of 1·6d. per gal. For this price a producer, regardless of the size of supply or distance from a centre, could have his milk collected and a clean, sterilised churn returned to him the following day. It is not surprising that such progressive changes for the better have brought about a virtual transformation in the industry—one of the most outstanding is a great increase in winter milk production. In 1949, the November to April inclusive sales off farms represented over 41 per cent. of the total for the year. This was an increase of 7½ per cent. on the 1939 figure, and on an estimated 1924 figure the increase was 16 per cent.

The picture, after the outbreak of war, was approximately thus: a rapidly expanding sale for liquid milk locally and for shipment to Great Britain, a maintenance of butter production and still a surplus for manufacture. In order to make the best use of the available surplus, it meant that haulage distances were often increased; this meant spoilage, and called either for heat-treatment or refrigeration, or both.

On behalf of the Ministry of Food, the Ministry of Agriculture erected and operated seven milk depots. All these were equipped with the most modern plant for H.T.-S.T. heat-treatment and cold storage of milk, drying of separated milk and washing of churns. These up-to-date centres made it possible to export pasteurised milk which normally stood up to the trying conditions involved. At the same time, many cross-channel firms erected factories for the manufacture of various milk products; these included condensed and evaporated milk, spray and rolled dried milk, National Dried Milk, chocolate crumb, together with many proprietary milk foods. The most recent (1949-50) assessment of the utilisation of milk sold off farms is:

	Gal.
Liquid sales at home	37,000,000
Shipment to Great Britain	4,500,000
Butter	9,000,000
Condensed milk	20,500,000
Milk powder	8,700,000
Miscellaneous products	4,900,000
Total	84,600,000

During the early forties, the area was fortunate in that it built up a substantial supply of milk-processing, transport and storage equipment. These enabled milk to be shipped to Great Britain and, despite delays in transport of anything up to 30 hr., the keeping quality was such that it was fit for the liquid market. From the safe milk angle the position was a happy one. As early as 1945 it was possible to schedule Belfast and district a safe milk area, this meant that Grades A and B (bottled on the farm), and pasteurised milk only could be sold on the liquid market. In 1949, this area was extended to include all urban districts and seaside resorts. Approximately 85 per cent. of all liquid supplies in the area is now (1950) pasteurised.

The position with regard to herd health is reasonably good. Mastitis, or as it is called locally, felon, is prevalent, and is undoubtedly the cause of very serious loss to the industry. No accurate data are available for tuberculosis, but it is fairly widespread. An Attested Herd Scheme has recently got going and there is obviously considerable lee-way to make up in this direction.

It is interesting to note that all liquid milk, whether raw or pasteurised, is subject to a very intensive system of hygienic control. Grades A and B have to conform to bacterial plate counts of not over 100,000 per ml. and 300,000 per ml., and coliform organisms must be absent in 1/100 ml. Pasteurised milk is also subject to a count of 100,000, with coliform organisms absent in 1/10 ml.—in addition, phosphatase tests are carried out daily to check heat-treatment efficiency.

Recently, new legislation aiming at higher standards in the industry has been introducted. This is the Milk Act (N.I.) 1950, and enables the Ministry of Agriculture to issue new Regulations covering the liquid milk market. After 1952, Grade B milk will be eliminated, and the only raw milk to remain on the liquid market will be Grade A (T.T.)—by 1954, Grade A herds must be attested. All other raw milk will be classified as produced under a milk licence. This grade cannot be sold on the liquid market in raw condition, but will have to be pasteurised. Wide powers are given to the Ministry of Agriculture to prescribe standards of quality, the terms of licences to include authority to inspect all cows from which milk is produced; the premises at which the milk is produced, and the methods of treatment and handling of the milk. Authority is given for the revocation of licences and penalties can be imposed for offences under the Act. The holder of a licence revoked or suspended by the Ministry can, after notice, appeal to the Courts. The Ministry of Agriculture will have power to operate plants for the processing of milk in areas where there is not already available the necessary plants and facilities.

It is clear from this brief survey that the dairy industry has made substantial progress, and this is specially true of the last decade.

IRON AS A TRACE ELEMENT IN MILK. Milk is poor in iron hence a diet of milk alone or unsupplemented by iron in one form or another may lead to nutritional anaemia. The liver, etc., of the young suckling mammal contains a sufficient supply of iron until the animal ceases to depend on milk for its food. *See* Constituents; Human milk; Nutritive value.

IRON IN DAIRY PRODUCTS. Although iron is far less effective than copper as a catalyst for oxidation, it can be the cause of taints and must be kept below a certain limit in dairy products. *See* Auto-oxidation; Metals.

Ref.: McDowell (1947), *JDR*, **15**, 70 (estimation).

IRRADIATED MILK. Milk in which the vitamin D content has been increased by irradiation by ultra-violet rays. Exposure of an animal, or certain foodstuffs, to ultra-violet waves has the same effect as supplying vitamin D to the diet. The effect is specifically the action of waves of length 300 to 310 mμ on sterols (p. 999) and while sunlight can be effective under favourable conditions, it is of little effect in cloudy atmospheres or after passage through glass. Proper irradiation can increase the vitamin D content (anti-rachitic potency) of whole milk 15 to 20 times. The precursor in animal fats, ergosterol, is converted into *calciferol*. *See* Vitamins.

Irradiated milk was being developed in this country before the war, but now that the synthetic vitamin is available at a low price, it is simpler and cheaper to add it to milk. Vitamin D is added to milk which is used for making baby foods. *See* Infant foods; Milk powder; Nutritive value.

IRRADIATION. The subjection of any material to the action of rays, especially ultra-violet rays, which are those just shorter than blue or violet light (about 400 mμ).

Irradiation is of importance in dairying because of the following effects: (i) production of vitamin D from ergosterol; (ii) destruction of bacteria; (iii) bleaching, especially of fats; (iv) production of certain taints such as burnt flavour (*see* Flavours); (v) production of reducing conditions in milk by catalysing the oxidation of the unsaturated fatty acids in the milk fat. Thus sunlight can cause the reduction of methylene blue and resazurin in milk.

$$\mathrm{MB} + \mathrm{R} \xrightarrow[\text{light}]{\mathrm{H_2O}} \mathrm{MB.H_2} + \mathrm{R.O}$$

MB	R	MB . H$_2$	R . O
methylene blue (blue)	oleic acid	reduced methylene blue (colourless)	oxidised oleic acid

See Pasteurisation, alternatives to.

IRREVERSIBLE REACTION. A chemical change which cannot be reversed. The precipitation of casein by rennet is an example.

Resazurin (p. 904) affords an example of both types:

$$\underset{\text{(blue)}}{\text{resazurin}} \xrightarrow{\textit{irreversible}} \underset{\text{(pink)}}{\text{resorufin}}$$

$$\underset{\text{(pink)}}{\text{resorufin}} \overset{\textit{reversible}}{\rightleftharpoons} \underset{\text{(colourless)}}{\text{dihydroresorufin}}$$

ISIGNY. A type of highly-flavoured butter.

ISO-ELECTRIC POINT. The *p*H or condition of an amphoteric substance, usually a protein, at which the substance is without electric charge or has an equal number of positive and negative charges, or charged radicles. Proteins are sometimes insoluble and therefore precipitated at their iso-electric point. Thus if milk, which contains casein as a dispersed phase or in colloidal solution, and normally has a *p*H of about 6·5, is adjusted to *p*H 4·6 the casein is precipitated, or the milk clots. Thus we have

at *p*H $>$ 4·6 casein + sodium hydroxide → sodium caseinate
at *p*H 4·6 casein (neutral and precipitated)
at *p*H $<$ 4·6 casein + hydrochloric acid → casein hydrochloride

Refs.: Richmond; Davies; Rogers.

ISOLATION OF BACTERIAL SPECIES. *See* Classification; Coliforms; Lactic acid bacteria.

ISO-OLEIC ACID OR ELAIDIC ACID. An isomer of oleic acid, M.P. 44 C. and having a lead salt insoluble in alcohol. It is usually estimated by Twitchell's method (*A* (1921), **46**, 466).

ISOTONIC DILUENT. When the solids-not-fat of the milk of a cow falls for any reason (mastitis, poor feed, season, individuality, etc.) there is a decrease in the lactose and casein contents but the freezing-point remains constant. There must therefore be an increase in other constituents to preserve the osmotic pressure. The increase is chiefly in *chlorides* and *water soluble proteins* which are characteristic of the isotonic diluent. It approaches blood and lymph serum in composition.

Refs.: Davies; Rogers; Davies (1933), *JDR*, **4**, 273.

ISSOGLIO RANCIDITY TEST. A modification of the permanganate method for estimating the amount of "oxidisable fatty acids" in rancid fat.

Ref.: Richmond.

ITALY.

Refs.: Simone (1949), *IDC*, **5**, 161; (1934), *The Milk Industry in Italy*, Rome.

J

JERSEY. *See* Breeding; Channel Islands milk; Legal aspects; Quality payment.

Ref.: Tubbs (1939), *The Book of the Jersey*, Hitchin.

JIMMY WEED. A poisonous plant (*Aplopappus heterophyllus* or rayless golden rod) which can be the cause of a type of milk sickness in America. The toxic substances can be excreted in the milk and affect calves and possibly man.

JOHNE'S DISEASE. A wasting disease of cattle and other animals caused by an acid-fast bacillus similar to the avian *Myco. tuberculosis*. The organism is called Johne's bacillus or *Myco. paratuberculosis*. The disease does not resemble tuberculosis, being a chronic enteritis and usually ending fatally. *See* Diseases of dairy cattle.

JOINT MILK QUALITY CONTROL COMMITTEE. *See* National Milk Testing Scheme.

JOULE. The unit of work equivalent to the energy expended when 1 v. drives 1 amp. of current through a resistance of 1 ohm for 1 sec. It is equal to 10,000,000 ergs or 1 watt-sec. or 0·738 ft. lb. or 0·24 cal. (small).

JOULE'S LAW. Heat generated in a circuit $=$ (current)^2 $\times$ resistance $\times$ time.

JOURNALS. *See* Literature of dairy science.

JUDGING. (i) *Of dairy cattle.* *See* Breeding; Management of cattle.

(ii) *Of dairy products.* This is carried out by graders who are experienced practical men, either former makers of butter, cheese, etc., or buyers. Grading is based on subjective tests, such as appearance, aroma, taste, and feel. Scientific apparatus is rarely or never used.

Graders (or judges) have a considerable influence on the type of butter, cheese, etc., made as in normal times they decide the price and since 1939 they have had the authority of a government department.

It is of interest to note that under normal conditions, factors will encourage that type of product which they can sell best, which is not necessarily the same as the best. *See* Butter; Cheese; Condensed and evaporated milk; Flavours; Grading; Milk powder.

Refs.: Nelson and Trout (1948), *Judging Dairy Products*, Milwaukee; Thomson (1925), *Grading Dairy Produce*, London.

JUNKET. The soft coagulum or gel formed by the action of rennet (p. 901) on sweet milk (*i.e.* non-soured) at a temperature of about blood heat. *See* Cheese, p. 168; Rennet.

JUST-HATMAKER PROCESS. This is virtually the original method of drying milk by the roller process. Two steam heated rollers at 250 to 270 F., practically touching, rotate inwards, the film of dried milk being scraped off by very accurately adjusted knives. *See* Milk powder.

K

KAELDER MILK. A Norwegian fermented milk of very good keeping quality, hence the name " cellar milk ". It is a mixed fermentation in which lactic acid bacteria hydrolyse the lactose, and torulae ferment the hexoses. The ripened culture contains about 0·5 per cent. alcohol and 2 per cent. or more lactic acid.

KAY-GRAHAM TEST. *See* Phosphatase test.

KEEPING QUALITY. Milk, whether raw or pasteurised, sooner or later becomes unfit for use on account of the growth of bacteria. The time elapsing from production or delivery to this point of unfitness for use is called its *keeping quality*. There is no precise definition of what determines keeping quality or the end-point, but the following have been used : (i) unfit because of objectionable odour or taste ; (ii) clot on boiling ; (iii) clot at room temperature.

(i) and (ii) are almost identical from the point of view of time, (iii) occurring some hours later. Clot on boiling is now generally accepted as a yard stick or end-point in keeping quality tests.

It has been claimed that feeding menadione (2-methyl-1, 4-naphthoquinone) to lactating cows will increase the keeping quality of the milk (Kelley and Dittmer (1953), *Abstr. Pap. Amer. Chem. Soc.*, Sept. 18A). *See* Bacteriological grading of milk ; Clean milk production ; Clot-on-boiling test ; Cooling ; Flavours ; National Milk Testing Scheme; Quality payment; Stability; and various dairy products.

Refs. : Min. Agric. (1932), " Guide to the Conduct of Clean Milk Competitions ", Bull. 46, H.M.S.O. ; Wilson *et al.*; Babad and Shenhav-Hetman (1952), *JDR*, **19**, 63 ; Egdell and Bird (1951), *DI*, **16**, 143.

KEEPING QUALITY OF PASTEURISED MILK. Owing to the unpredictable nature of the flora surviving pasteurisation in relation to acid and rennet production, it is difficult to forecast the keeping quality of pasteurised milk by any test on the raw milk. Broadly speaking, we can assert that a raw milk of good hygienic quality, *e.g.* plate count less than 200,000, will give a pasteurised product of good keeping quality, *e.g.* greater than 36 hr. at 18° C. but a poor quality raw milk, *e.g.* plate count of say 30,000,000, may or may not give a pasteurised milk of good keeping quality. *See* Heat treatment at country depots ; Pasteurisation ; Stability ; Thermoduric bacteria.

Ref. : Phillips (1946), *SAB*, p. 94 (bottle contamination).

KEFIR OR KEPHIR. This fermented milk drink is unique in containing curious solid clusters of casein, bacteria, and yeasts. The culture is propagated by transferring the " cauliflower heads " to fresh cow's milk. These are filtered off before drinking but are necessary for propagation. They may be dried, and keep their vitality for some time.

The flora consists of lactose-fermenting torulae, *Str. lactis*, and various lactobacilli including *L. caucasicus*.

Refs. : Burke ; Hammer ; Orla-Jensen ; Schulz (1946), *M*, **1**, 19.

KENYA.

Ref. : Barnett (1951), *DI*, **16**, 250.

KERR RANCIDITY TEST. *See* Issoglio rancidity test.

KETOSIS. The presence of ketones or " acetone bodies " in the blood, urine and breath of animals due to incomplete oxidation of carbohydrate.

Refs. : Saarinen and Shaw (1950), *JDS*, **33**, 515.

" KEXEY " TAINT. *See* Cheese, p. 168.

KHOA. An Indian concentrated milk made by stirring milk in an open pan over a fire.

Ref.: Iyer *et al.* (1948), *IJDS*, **1**, 117.

KIRSCHNER METHOD. This analytical method for butyric acid is based upon the solubility of silver butyrate in dilute silver nitrate solution. It can be practised as a continuation of the Reichert-Polenske method (p. 901) but usually gives values about 20 per cent. high, due to the fact that the silver salts of the higher acids are not completely insoluble.

Refs.: Kirschner, *A* (1905), **30**, 205 ; Cocks and Nightingale, *A* (1928), **53**, 322 ; *A* (1929), **54**, 96 ; Richmond.

KJELDAHL METHOD FOR NITROGEN. This is the almost invariably used routine method in this country, and proteins are commonly assayed by this method. It is based upon the fact that practically all the nitrogen in biological substances is converted into ammonia when boiled up with strong sulphuric acid in the presence of selenium or copper sulphate as a catalyst. The ammonia is estimated by alkalising the acid and steam distilling into a known volume of standard acid using congo red as an indicator.

Ref.: Richmond.

KNAPOST. *See* Pultost, p. 199.

KOESTLER NUMBER. *See* Chloride content of milk.

KOSHER. The word *Kosher* means " prepared in accordance with Jewish ritual law ". It does *not* mean " pure ", " hygienic ", or " unadulterated ", although it may frequently come to mean that.

In Jewish law it is permitted to drink only milk produced by animals which possess cloven hooves and chew the cud, *e.g.* the cow, sheep, goat, deer. The milk of a mare, camel, etc., is not permitted, and is therefore not *Kosher*. In ancient times, and even in some parts of the near East now, the milk of the mare and camel are still frequently used, and these, even when added in minute quantities to cow's milk, render it unsuitable for consumption by an orthodox and practising Jew.

The code of Jewish laws, drawn up by *Maimonides* (1135-1204 C.E.), therefore states clearly that only cow's milk may be consumed. As numerous instances occurred where actual adulterations of the cow's milk with milk of other animal species occurred, the Jewish law was forced to enact a sequel, namely, that only milk produced in the presence of a person of the Jewish faith could be relied upon to be *Kosher*. It is true that present English law makes it illegal to designate anything but cow's milk as " milk ", but it must be remembered that the same English law also forbids the addition of water or removal of fat from cow's milk. In spite of this enactment, prosecutions for adulteration of milk are not uncommon, and an orthodox Jew would feel that he had morally transgressed by consuming other than cow's milk. Water, of course, is *Kosher*, hence cow's milk deficient in fat or adulterated with water is still a *Kosher* product. In other words, adulteration in English and Jewish law are not synonymous. *Kosher* milk then is milk produced by a cow, sheep or goat and unadulterated with milk from another animal species. There is no legal limit as to fat or water content, but it must have been milked or produced by, or in the presence of, an orthodox Jewish person to ensure that no adulteration has taken place. The above applies to milk consumable all the year round, except Passover.

Passover Kosher Milk. During the festival of Passover, when Jews celebrate in memory of their exodus from Egyptian slavery, they refrain from eating bread or any other food in which a natural souring, *e.g.* as in dough or beer, has taken place. Instead they consume unleavened bread or Matzo. All other foods must be scrupulously guarded from contamination with bread during the 8 days of Passover. Thus *Kosher* milk into which a crumb of bread had inadvertently fallen is not fit for consumption during the week of Passover. Apart from Passover week, a crumb of bread (or a drop of beer or vinegar) would be harmless, and would not render the milk " not Kosher ". Thus, a milkman eating during any of the operations in milk production or processing would be a source of danger to Passover milk production. Hence the necessity for supervision during production of milk for Passover.

Further, all vessels used in the handling of milk must be new or specifically preserved only for this purpose. A pail in which a cow had been fed could render milk production for Passover most difficult, if not impossible.

Kosher Dairy Products. *Butter.* As butter is the churned fat obtained from milk, it follows that Kosher butter can be made from Kosher milk (*i.e.* under supervision). Providing the churn, vessels, etc., are used for no other purposes, the butter will be Kosher. The use of soap (animal fats) is forbidden in the production of Kosher food products.

Cheese. This presents more difficulty, for the rennet has to be obtained from a Kosher animal, *e.g.* cow, goat, etc., and the animal must be killed according to Jewish law. The rennet of the pig would be absolutely forbidden. There is still some controversy as to whether rennet obtained from a calf's stomach and dried to a powder is suitable or not, *i.e.* can obtain the sanction of being Kosher. In the U.S.A. Marshall's and Hansen's both produce a Kosher rennet.

Cottage cheese made of sour milk and not requiring rennet is, of course, Kosher, and popular among many sections of Jewish people.

KOSHER CHEESE. *See* Cheese, p. 195.

KÖTTSTORFER VALUE. A method for assaying butterfat based on the fact that butterfat requires more alkali for its saponification than other fats. Butterfat requires 221 to 233 mg. KOH per g. of fat for complete saponification.

Refs.: AOAC; Richmond.

KOUMISS. *See* Kumiss.

KRAUSE DRYING PROCESS. This is one of the most important spray-powder methods in which the milk is atomised by falling on to a rapidly revolving disc. *See* Milk powder.

KREIS TEST. The classical test for rancidity in edible fats and oils. The fat is mixed with benzene and hydrochloric acid, and then treated with a little phloroglucinol in alcohol, shaken 1 min. and then centrifuged. The colour is then matched in a Lovibond tintometer. *See* Auto-oxidation ; Rancidity.

Refs.: AOAC; Davies ; Richmond ; Williams, K. A.; Lea (1938), *Rancidity in Edible Fats*, H.M.S.O.

KUMISS OR KUMYS. A Russian fermented milk prepared in open vessels. The flora consists of lactose-fermenting torulae and lactic acid bacteria, largely of the *L. bulgaricus* type.

Refs.: Burke ; Orla-Jensen.

LABELLING OF FOODS ORDER. *See* Food and Drugs Act; Legal aspects; Standards.

Refs.: Bell; Swift; "The advertising, labelling and composition of food," 1949, H.M.S.O.

LABORATORY CONTROL. *See* Accuracy; Bacteriological grading; Fat; Management of creameries, of pasteurising depots; Methylene blue; Resazurin; Routine tests; Solids-not-fat; Testing milk supplies.

Refs.: Chalmers; Ling; Richmond; *Milk Testing*; *LCDP*; Davis and Ashton (1951), *JSDT*, **4**, 78.

LABORATORIES, ORGANISATION OF. Function and Design. The true function of a laboratory in industry is the proper control of all technical processes taking place in the factory. The importance of the creamery laboratory, therefore, lies in the fact that it should relieve the manager of as much responsibility as possible in technical control. This can be possible only when the laboratory is staffed by properly trained personnel who are allowed to have initiative, not only in the carrying out of the tests but, what is more important, in their interpretation.

It is difficult to lay down categorically a size for a creamery laboratory as so much depends upon the function of the creamery and what tests are to be performed. It may be suggested, however,that 0·5 sq. ft. per producer sending into the creamery with a minimum of 200 sq. ft. should be regarded as a suitable area; in addition special apparatus and special tests should occupy separate rooms. Thus, any work resulting in the emission of steam or smells should be carried out in a separate room with a properly constructed fume chamber. Balances and other delicate apparatus should likewise be housed in a separate room.

In a laboratory of any size, employing a staff of more than two, there should be provided a separate office for the head of the laboratory, in which all records may be kept and interviews held.

The best type of lighting for a laboratory is undoubtedly overhead roof lighting with fluorescent lamps when daylight is inadequate, as this is best for scientific work and, in addition, allows the utilisation of the maximum wall space for cupboards, shelves, and apparatus.

Probably the best shape is a not too narrow rectangle, as this gives a fair bench space and allows all parts of the laboratory to be easily accessible. If possible, the middle of the laboratory should be kept clear with the exception, perhaps, of a small table and chair for writing. Cupboards should be plentiful not only to protect the apparatus, but to permit of tidiness and cleanliness in laboratory work. Any apparatus or article should be cleaned and replaced in its "home" immediately after use.

Teak is the only wood which really stands up to laboratory work and stainless steel around sinks is a commendable luxury. All material in the laboratory should be of the easily cleaned type, such as white tiles or smooth surfaces covered with a washable paint. Always err on the plentiful side with sinks, taps, power-plugs, and light-points.

The position of the laboratory in the creamery is a somewhat more controversial matter. Roof lighting naturally implies a position on the top storey unless the laboratory can be built out from the main building. It is strongly recommended, however, that the laboratory should be reasonably near the intake platform unless a trolley or sub-laboratory is available. Nearness to the intake platform means noise and steam which are undesirable. Each case must, therefore, be treated on its own merits.

A B.Sc. (Dairying) or a N.D.D. with experience of creamery methods, should be the minimum qualifications for a person in charge of a laboratory in a large creamery or dairy.

Tests. This section covers the requirements of creameries dealing with liquid milk, cheese, butter, and dried and condensed milk. The technical control necessary will be dealt with in this order, and the scope of the tests described is summarised in tables Lb I, II and III.

TABLE Lb I

CREAMERIES HANDLING LIQUID MILK ONLY. TESTS FOR PRODUCERS' MILK.

Information required	*Possible tests*
Keeping quality	Plate count Microscopic count Keeping quality test (smell, taste and clot-on-boiling) Methylene blue at 37° C. Methylene blue at 18° C. Resazurin at 37° C. Resazurin at 18° C.
Visible dirt	Sediment pad Centrifuged deposit
Fat	Gerber Babcock Gravimetric
Total solids and solids-not-fat	Hydrometer method Gravimetric
Added water	Freezing-point
Mastitis	Catalase Rennet Mastitis index Special plating methods Chloride or conductivity Casein number
Special bacteriological faults :	
(*a*) Ropiness	
(*b*) Sweet curdling	
(*c*) Colour faults	
(*d*) Taints and off-flavours	
General suitability for acceptance on the platform	Smell Acidity (*p*H) Rapid (10-min.) resazurin

Sampling. Correct sampling is the foundation of all analysis and unless the sampling is properly carried out the most careful subsequent analytical care is useless. The importance of sampling is not always realised even by highly trained scientific workers. In dairy work, samples may be required for bacteriological or for chemical tests, and quite different aspects have to be considered for these. In bacteriological tests, aseptic precautions and sterile containers are far more important than the homogeneity of the sample ; for chemical tests, the reverse holds good. It is obviously a great convenience if the same sample can be used for both chemical and bacteriological tests. Nevertheless, accuracy is far more important than convenience, and failure to consider this point has sometimes resulted in many laborious hours being spent in getting results that are not worth the paper they are written on.

A good example of this point is the sampling of milk from individual producers for the methylene blue, fat, and solids-not-fat tests. Practically all creameries

TABLE Lb II—OTHER TESTS IN CREAMERIES HANDLING MILK ONLY

Material	*Information required*	*Possible tests*
Milk in bulk	Keeping quality	Titratable acidity, etc.
	Fat, etc.	Gerber
	Protein	Kjeldahl " Walker " casein
	General suitability for acceptance	Titratable acidity, *p*H, 10-min. resazurin
Churns, tanks, pipes, and bottles	Sterility	Churn resazurin Plate count of rinse or swab Milk souring organisms
Detergents	Strength	Titratable alkalinity, *p*H, conductivity
Disinfectants	Strength	Available chlorine
Pasteurised milk	Efficiency of pasteurisation	Phosphatase Methylene blue or resazurin
	Post-pasteurisation contamination	Coli Other tests
Sterilised milk	Efficiency of sterilisation	Turbidity test

TABLE Lb III—MANUFACTURING CREAMERIES

Material	*Information required*	*Possible tests*
Liquid milk	As on	page 1007 and above
Cheese	Acidity (whey)	Titratable acidity *p*H
	Acidity (curd)	*p*H
	Moisture	Gravimetric
	Pitching point	Superficial density
	Firmness	Rheological
	Yield	Calculation
	Fat	Gravimetric
	Salt	Silver nitrate titration
Butter	Moisture	Gravimetric
	Salt	Silver nitrate titration
	Fat	Gravimetric
	Curd	Gravimetric (difference)
	Volatile, etc., acids in fat	Reichert, Polenske and Kirschner
	Copper and iron Rancidity Peroxide oxygen in fat Colour	B.S. Spec. No. 769
	Bacterial count	B.S. Spec. No. 895
Milk powder	Moisture	
	Fat	
	Solubility	
	Rancidity and oxidation	
	Bacterial count	
	Colour (age)	
Condensed milk	Total solids	
	Fat	
	Sucrose	
	Colour (age)	
	Bacterial count	

formerly took their samples from the weighing tank. This is undoubtedly the best method for getting a sample for fat testing, but bacteriological testing introduces another consideration. What happens if a good quality milk follows a dirty milk? The contamination is obvious—is it significant? The answer is that it depends on the badness of the contaminating milk and on the treatment of the sample. If the difference in the qualities of the milks is not great, *e.g.* of the order of 10 : 1, as when the counts are 1,000,000 and 100,000—and the milk is tested immediately by a short-time test such as the resazurin or methylene blue test at 37° C., the error is not likely to be significant. If, however, the difference is great, *e.g.* counts of 10,000 and 10,000,000, or if the sample is tested by a long-time test such as the methylene blue at 18° C., or if the sample is held for a certain period, *e.g.* up to 24 hr., after the time of production, then the error is highly significant and the result quite untrustworthy. The ideal solution is the thorough plunging of all churns sent in by the producers with sterile plungers—and the taking of a composite sample—into a sterile container. This is, however, a tedious process and it is better in practice to take a sample aseptically from, say, two or three churns without thorough plunging for *bacteriological* purposes, and a sample from the weighing tank into a non-sterile container for *chemical* testing. Efficient platform testing would " weed out " bad milks and so permit weigh-tank sampling for bacteriological tests.

Accuracy and permissible error. Another aspect that is too often ignored or unrealised is the inherent error of the method. No measurement is ever absolutely accurate—there is always a probability range. Even in inorganic chemical analysis, where strengths of solution are often given to four significant figures, the fourth figure is usually meaningless, and in biochemical analysis an accuracy of 1 per cent. is only rarely obtained. As an illustration of this point we may consider the problem of calculation of cheese yield from the fat and solids-not-fat content. If a creamery is converting 100,000 lb. of 3·5 per cent. fat, 8·5 per cent. solids-not-fat milk into cheese, and the yield formula is fat + $\frac{5}{6}$ solids-not-fat, the error in estimating the yield may be deduced as follows: the error in the Gerber method may be 0·05 per cent. and in the solids-not-fat determination by hydrometer 0·1 per cent., *i.e.* a fat value of 3·5 may be 3·55 or 3·45 and a solids-not-fat value of 8·5 may be 8·4 or 8·6. A 0·05 per cent. error in determining $100{,}000 \times \frac{3{\cdot}5}{100}$ lb. of fat is 50 lb., and a 0·1 per cent. error for $100{,}000 \times \frac{8{\cdot}5}{100}$ lb. S.N.F. is 100 lb. S.N.F. The possible error in calculating cheese yield is therefore $50 + \frac{5}{6}(100) = 135$ lb.

In dealing with bacteriological tests the error is so enormous that it is best to think in terms of " order of ". Thus instead of saying that the bacterial count of a milk, butter, or cheese is, say, 1,200,000, it is preferable to say that the count is of the order of 1,000,000. There is no harm, of course, in reporting the actual colony count, *e.g.* 1,200,000, provided that the error of the method is realised. In the past there has been a tendency for some people to regard a count of 500,000 in a milk as indicating a superior quality to another milk of count 510,000. This is only one reason why no producer should be judged on the basis of a single test.

Standardisation of technique. Fortunately in this country many techniques for analytical methods in dairy science are now standardised. Considerable confusion has occurred in the past because creameries have used different techniques. Whenever a technique has been laid down and generally accepted, it should be most carefully followed.

The possible error in any analysis must always be borne in mind when reporting and interpreting results. It is desirable to make all determinations in duplicate when any special importance is attached to the result. As routine tests for fat, solids-not-fat, and resazurin or methylene blue are made every week or fortnight, and the producer's milk judged on the average of several values, this is not necessary in the case of these tests. The greater the inherent error of the method, or the sampling error, or the more numerous the manipulations involved, the more important it is to make analysis in duplicate. Thus the Gerber test is simple and fairly accurate, but the hydrometer method for solids-not-fat is less accurate because of the variability in the ageing effect on the density of the fat globules. The determination of moisture in cheese is very difficult, the errors being due to sampling and the complicated way in which water is attached to the solids in cheese. The determination of casein nitrogen is also subject to errors of separation of proteins, in the digestion with sulphuric acid and in titration. Analyses such as these last two should, therefore, always be done in duplicate, and if reasonable agreement is not obtained between duplicates the analysis should be repeated. Different methods have different errors, and the importance of standardisation in methods lies in the standardisation of these errors. For many purposes all that is required is information of any deviation from the normal, as, *e.g.* in moisture in cheese, and any *constant* error in the determination is not really of any significance. We may now consider the sources of error in more detail.

Analysis of results. In dairying it is frequently of interest to know if one factor varies with another, *e.g.* is a specific fault in the cheese due to a certain high coli content in the milk, or to colostrum, or to non-sterilising of the vats, etc. ? We are here faced with a limited number of observations and still more limited opportunity for experimenting, while the " biological variation " is large. It is necessary, therefore, to employ some form of statistical method for the elucidation of such problems. The following elementary statistical conceptions and terms should, therefore, be studied and understood : random selection and planning of experiments ; distribution ; reproducibility and accuracy of measurement ; variability and standard deviation ; standard error ; coefficient of correlation, coefficient of variation ; significance of differences between means.

The reader may be recommended to study firstly Elderton and Elderton's *Statistics*, and later Dawson's *Introduction to the Computation of Statistics* (University of London Press), or Tippett's *Methods of Statistics* (Williams and Norgate). *See* Statistical formulae.

The " scatter diagram " is a good method for the preliminary examination of data. This is always advantageous, even when more elaborate methods are to be used later, as this method gives a picture which the eye can easily take in. As a simple method of measuring the closeness of correlation the following procedure may be employed : mark off that 5 per cent. of the points which is obviously most scattered, *i.e.* farthest from a diagonal line through the points across the graph, and discard this fraction. Then draw two lines from opposite corners through the outermost of the remaining points. The ratio of the area outside these two curved lines to the total area of the rectangle is then a measure of the correlation. The area outside may be computed by counting the squares, the fractions being estimated to the nearest tenth. Thus if the points fall on a straight or curved line, the ratio is 1 ; if a complete scatter is obtained, the ratio is about 0·05.

The coefficient of correlation is the value most commonly given, but it can only be used when the relationship is linear. The coefficient of variation is independent of linearity and has the further advantage that the scatter at different levels can be quantitatively expressed.

Books for the laboratory. In the following list one asterisk indicates that the book should be *permanently* in the possession of the laboratory ; those with two asterisks may be circulated amongst creameries.

(1) *British Standards Nos. 696, 734, 769, 770, 892, 1741, 1742, 1743 ; *Ling, *Dairy Chemistry* or *Wright, *Agricultural Analysis* ; *Chalmers, *Bacteria in*

TABLE Lb IV

REAGENTS FOR BIOCHEMICAL TESTS ON BACTERIAL CULTURES

Test	*Reagent*	
Voges-Proskauer	40 per cent. sodium hydroxide	
(acetoin and diacetyl)	Creatine (solid)	
Indol	*Ehrlich's Reagent:*	
	(1) Paradimethylamino-benzaldehyde	4 g.
	96 per cent. alcohol	380 ml.
	Conc. HCl	80 ml.
	(2) Sat. aq. potassium persulphate	
Hydrogen sulphide	1 per cent. lead acetate (absorbed in filter paper)	
Catalase	1 per cent. (3 vol.) hydrogen peroxide	
Nitrite	*Ilosvay's Reagent:*	
	(1) 30 per cent. glacial acetic acid sat. (hot) with sulphanilic acid	
	(2) 6 g. dimethyl *a*-naphthylamine, 1000 ml. 30 per cent. glacial acetic acid	
Ammonia	*Nessler's Reagent:*	
	(1) Potassium iodide	62·5 g.
	Water	250 ml.
	(2) Sat. mercuric chloride	
	(3) Potassium hydroxide	150 g.
	Water	150 ml.
Gelatin and casein hydrolysis	1 per cent. tannic acid (freshly prepared)	
Phenol	(1) *p*-nitraniline	
	(2) Sodium nitrite	
Methyl red	Use ordinary indicator solution	
Oxygen indicator	(1) 5 ml. N/9 NaOH	
(for anaerobic work)	95 ml. water	
	(2) 3 ml. methylene blue (staining solution)	
	97 ml. water	
	(3) 5 per cent. dextrose	
	(Mix equal volumes and boil)	

Relation to the Milk Supply or *Cunningham, *Practical Agricultural Bacteriology*; Davis, *Milk Testing;* Davis, *Laboratory Control of Dairy Plant;* *House, *Bacteriological Control of Milk*, Camb. Univ. Press; **American Public Health Assoc., *Standard Methods for the Examination of Dairy Products*, 9th ed.

Descriptions of methods will also be found in ***J. Dairy Res.*, *J. Dairy Sci.*, *Analyst*, **Dairy Industries*, *Food Manufacture*, and *Official Methods of the Association of Official Agricultural Chemists.*

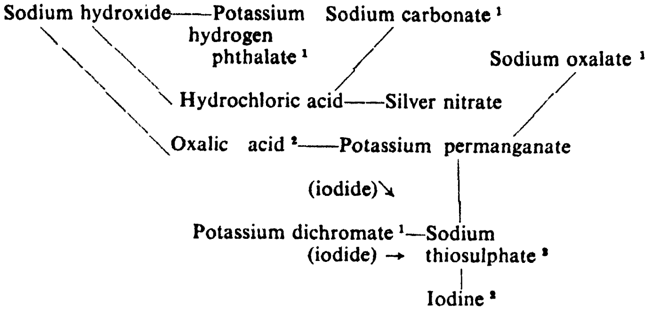
(2) *Davies, *Chemistry of Milk* or *Richmond, *Dairy Chemistry*; **Wilson *et al.*, *Bacteriological Grading of Milk*; **Associates of Rogers, *Fundamentals of Dairy Science*; **Orla Jensen, *Dairy Bacteriology* or **Hammer, *Dairy Bacteriology*; Harvey and Hill, *Milk Production and Control* (Lewis); Cronshaw, *Dairy Information.*

(3) ***Dairy Science Abstracts.*

The Biennial reviews in the *J. Dairy Res.* should also be read. *See* Literature of dairy science.

STANDARD SOLUTIONS.

All chemical analysis depends upon the accuracy of standard solutions, and these should be constantly checked by the head of the laboratory or a qualified assistant. The following scheme shows how the common standards can be cross-checked.



Only *Analar* or purest obtainable chemicals and CO_2-free distilled water should be used.

See Classification ; Coliforms ; Media ; Routine tests ; Sampling ; Testing of milk supplies ; Various tests (by name).

Refs. : *Laboratory Practice* (various articles) ; Coleman (1951), *Laboratory Design* ; Lang (ed.) (1949), *Laboratory and Workshop Notes* ; (1951), *Further Laboratory and Workshop Notes*.

LABORATORY REPASTEURISATION TEST. A test for the efficiency of processing. The milk is pasteurised (30 min. at 63° C.) in the laboratory and plated. If the colony count is appreciably lower after laboratory pasteurisation, it indicates inefficient processing or contamination by plant. *See* Pasteurisation ; Phosphatase test. *Refs.* : Cuttell ; *Milk Testing* ; *LCDP*.

LABOUR SAVING IN DAIRIES. *See* Design of dairies ; Mechanical handling.

Refs. : Procter (1948), *JSDT*, **1**, 136 ; White, 138.

LACTALBUMIN. *See* Albumin.

LACTASE. An enzyme which splits lactose into its constituent hexoses, dextrose and galactose. The evidence for its existence in milk is unsatisfactory.

LACTATION. (i) The secretion of milk (*see* Milk secretion) ; (ii) the period of milk secretion from parturition to the final " drying off " or cessation of milking. *See* Composition, factors affecting ; Management of dairy cattle.

Refs. : Sikka (1950), *JDR*, **17**, 231 ; Silver (1952), *DSA*, **14**, 65, 41 (review) ; Pontecorvo (1940), *JDR*, **11**, 113 (persistency in lactation curve).

LACTENIN. A nitrogenous substance in milk which is claimed to have a restraining effect on the growth of bacteria in milk for some hours after it leaves the cow. *See* Germicidal action of milk.

Ref. : Auclair (1953), *IDC*, **3**, 1130 ; Jones and Simms (1930), *J. exp. Med.*, **51**, 327.

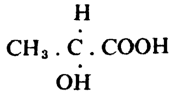
LACTIC ACID. As the name indicates, lactic acid is the characteristic acid of sour milk, being produced from the lactose by the lactic acid bacteria, coliforms and many other types of saccharolytic organisms. Milk clots on boiling when the initial titratable acidity (p. 6) has increased from 0·14 to about 0·23 per cent " lactic acid ". At room temperature milk clots at about 0·6 per cent., the final acidity reaching about 1 per cent. lactic acid which is the limit of growth for the streptococci (pH *c.* 4·2) although the lactobacilli can increase the acidity to 1·5 per cent. or higher (p. 583).

[1] If powdered and dried can be weighed out to make an accurate solution.

[2] Unstable ; requires frequent standardisation.

LACTIC ACID BACTERIA

Lactic acid is chemically α-hydroxy propionic acid



$$\mathrm{CH_3\,.\,\overset{H}{\underset{OH}{C}}\,.\,COOH}$$

and as the central carbon atom is asymmetric, the molecule exists in two forms or as optical isomers. These are known as dextro (*d*) and laevo (*l*) forms; a mixture of the two in equal proportions is optically inactive and termed the racemic (*r*) form. Bacteria may produce *d*, *l*, or *r* lactic acid and this characteristic is a central feature in Orla Jensen's classification of the lactic acid bacteria.

Lactic acid is a thick hygroscopic syrup, the purest " lactic acid " containing about 75 per cent. of the acid plus 10 per cent. lactide. This latter is an anhydride form and when making a solution of known strength, the solution should be boiled for 1 hr. or aged for 24 hr. at room temperature before standardisation.

Refs.: Kleinert (1953), Mitt. lebensom. Hyg, **44**, 232; Davidson (1949), *JDR*, **16**, 209; Ling (1951), *JSFA*, **2**, 279 (determination).

LACTIC ACID BACTERIA. Classification of the Lactic Acid Bacteria. This classification has been framed to provide a simple and elastic scheme capable of absorbing new findings and avoiding the difficulties encountered in trying to make existing schemes fit in with all known facts. Some schemes suffer noticeably from rigidity and limited outlook on account of the fact that bacteriologists have concerned themselves primarily with one field to the exclusion of others. In most cases undue prominence has been given to certain aspects, *e.g.* type of " haemolysis " in blood agar, optical rotation of lactic acid produced, and fermentations of sugars. A critical and detailed study of these characteristics frequently shows that they may be inconstant and hence misleading.

The classification is as follows (Fig. LAB 1):

STREPTOCOCCUS (round, kidney-shaped, or oval cells in pairs or chains).

Homofermentive (carbohydrates fermented almost entirely to lactic acid):—

Group I. Non-pathogenic types saprophytic on animal and plant matter.
Group II. Pathogenic and haemolytic types.
Sub-group (*a*) Primarily haemolysin producers.
(*b*) Primarily H_2O_2 producers.
(*c*) Resistant types tending to be heterofermentive.

Heterofermentive (appreciable amounts of carbon dioxide, alcohol, acetic acid, etc., formed):

Group III. Types saprophytic on plant matter.
(= *Betacoccus*, Orla-Jensen; = *Leuconostoc*, van Tieghem).

LACTOBACILLUS (rod forms).

Homofermentive:

Group I. Types saprophytic on plants (medium temperature).
(= *Streptobacterium*, Orla-Jensen).
Group II. Types saprophytic on plant and animal material (high temperature) (= *Thermobacterium*, Orla-Jensen).

Heterofermentive:

Group III. Types saprophytic on plant material.
(= *Betabacterium*, Orla-Jensen).

This classification is based primarily on the study of the metabolism of " resting " cells.

The streptococci can be classified in three main groups. The first consists of homofermentive, mesophilic, saprophytic types (*Str. lactis*, *Str. cremoris*, *Str. bovis*, and *Str. thermophilus*) having little or no respiration and producing practically only lactic acid. The second group consists of the pathogenic and potentially

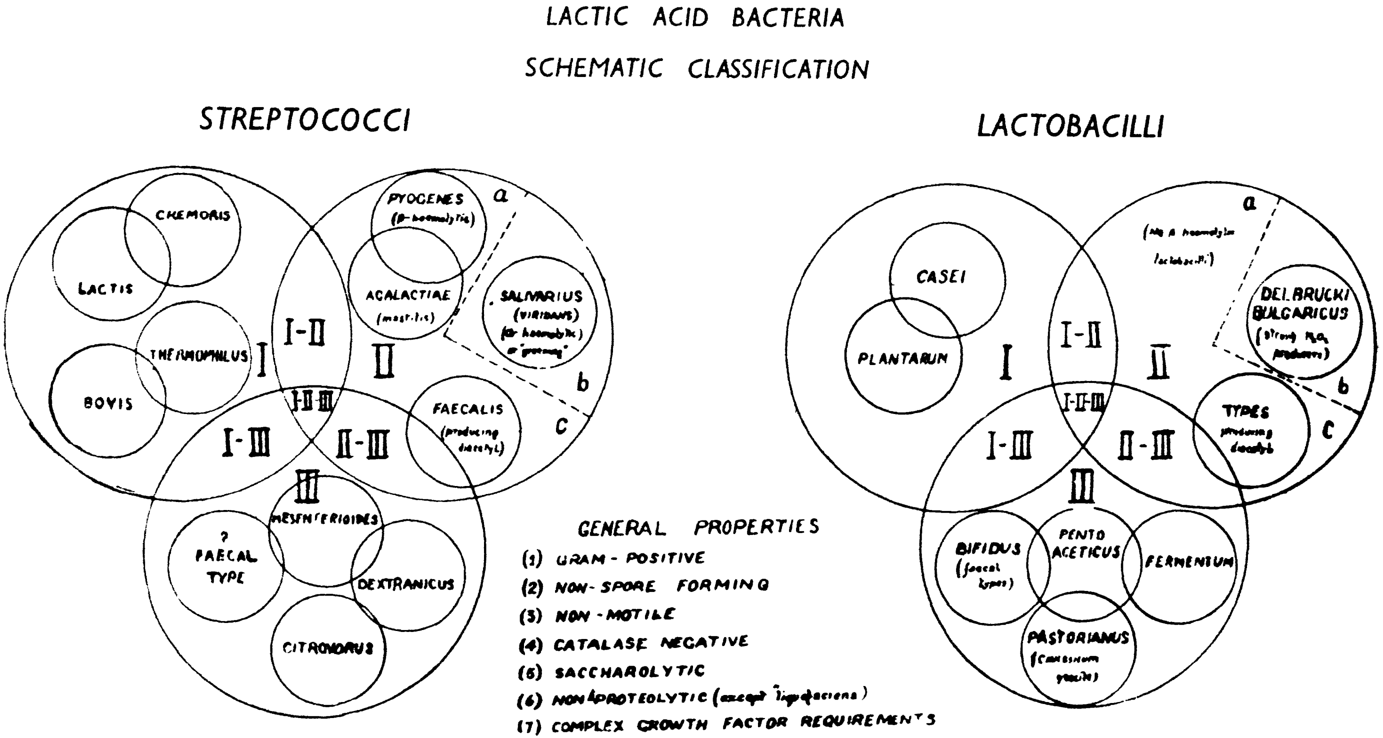

LACTIC ACID BACTERIA
SCHEMATIC CLASSIFICATION
STREPTOCOCCI
CHEMORIS
LACTIS
THERMOPHILUS
BOVIS
I
I-II
II
I-II-III
I-III
II-III
III
PYOGENES
(β-haemolytic)
AGALACTIAE
(mastitis)
a
SALIVARIUS
(viridans)
(α-haemolytic)
b
FAECALIS
(producing diacetyl)
c
MESENTERIOIDES
? FAECAL TYPE
DEXTRANICUS
CITROVORUS
LACTOBACILLI
CASEI
PLANTARUM
I
I-II
II
I-II-III
I-III
II-III
III
a
(No β haemolytic lactobacilli)
DELBRUCKI
BULGARICUS
(strong H₂O₂ producers)
b
TYPES
(producing diacetyl)
c
BIFIDUS
(faecal types)
PENTO ACETICUS
FERMENTUM
PASTORIANUS
(Caucasian yeasts)
GENERAL PROPERTIES
(1) GRAM - POSITIVE
(2) NON - SPORE FORMING
(3) NON - MOTILE
(4) CATALASE NEGATIVE
(5) SACCHAROLYTIC
(6) NON-PROTEOLYTIC (except liquefaciens)
(7) COMPLEX GROWTH FACTOR REQUIREMENTS

FIG. LAB 1.

pathogenic streptococci and can be divided into three well-defined sub-groups, all actively respiring. The first sub-group contains the haemolytic types (*Str. pyogenes*) ; these do not produce hydrogen peroxide and their respiration is largely inhibited by KCN. The second sub-group (*Str. salivarius* or " viridans ") produces hydrogen peroxide equivalent to half the oxygen absorbed and is not inhibited by KCN. The third sub-group (*Str. faecalis* and *Str. liquefaciens*—the " enterococci ") respire actively but differ from the first two sub-groups in that, of the total acid produced under aerobic conditions only about 50 per cent. is lactic acid, and small amounts of diacetyl and acetoin are produced. The third main group is heterofermentive (*Str. mesenteroides*, *Str. dextranicus*, and *Str. citrovorus*) and respire without the production of hydrogen peroxide. More lactic acid is apparently produced aerobically than anaerobically, and less than 50 per cent. of the total acid produced aerobically is lactic acid. Methylene blue initiates respiration in some species in Group I and depresses it in Group III. None of the strains contains catalase.

Similar work on the lactobacilli has shown that these can be classified into three main groups in the same manner as the streptococci. Group I shows a very slight respiration, which is not inhibited by cyanide and is very strongly stimulated by methylene blue, the stimulation being more pronounced than with the streptococci. Further, the hydrogen peroxide remaining at the end of an experiment is usually considerably sub-theoretical, this not being the case with the streptococci.

Group II is characterised by a higher respiration, which is inhibited by monoiodoacetate and stimulated by methylene blue, the theoretical quantity of hydrogen peroxide being found. The sub-group corresponding to the haemolytic streptococci is absent, and no rods in this group have their respiration inhibited by cyanide as with the pyogenic streptococci. There is a sub-group which corresponds to the faecal streptococci in producing diacetyl ; the rods differ, however, in producing only lactic acid aerobically. Group III (heterofermentive) rods behave exactly analogously to the corresponding group of streptococci, and differ from Groups I and II in having an apparently negative Pasteur reaction and a respiration partially inhibited by both cyanide and monoiodoacetate. No rod types have been found analogous to *Str. thermophilus* in failing to react under the conditions of metabolism experiments.

The first really systematic study was made by Orla-Jensen and his classical monograph is the greatest contribution to the study of these bacteria. More recent studies have been summarised by Sherman and in Bergey's Manual.

As an example of the general confusion existing amongst bacteriologists, and even more so amongst biochemists, may be cited *L. helveticus*, the organism which has lately become so well known by its use for microbiological assays of riboflavin and other growth factors. Originally isolated from Swiss cheese it was called *Bacterium casei* ε. Orla-Jensen re-named this organism *Thermobacterium helveticum* (here called *L. helveticus*) and named another type *Streptobacterium casei* (here called *L. casei*). The general adoption of *Bact. casei* ε, or *L. casei* ε, led to the dropping of the " ε " with the result that the two types have frequently been confused.

Choice of Species Names. Early descriptions of the so-called " type organisms " are often relatively so meagre that it only serves to increase confusion to adhere to these as type standards.

It has been considered preferable to use simple, well-recognised and descriptive names and, where feasible, those having claim of priority. Names have been chosen from a point of view of suitability and simplicity as well as priority.

The Lactic Acid Bacteria in Dairying. The lactic acid bacteria represent the most important single group of bacteria in the dairy industry, and the identification of the various types is obviously a matter of importance.

The scheme here outlined deals primarily with those types likely to occur in milk and milk products.

Ecologically considered, there are two broad groups of lactic acid bacteria: plant strains of which *L. pentoaceticus* is typical, and animal strains of which *Str. pyogenes* is an example. The typical bacteria of milk products and soured vegetable mashes represent two special sub-groups of these main groups, the organisms obtaining their energy by the fermentation of milk sugar and plant sugars respectively. In addition there are a number of types which, although obviously of animal or plant origin, also grow well in milk. These may be considered as adapted types.

Familiar examples are *Str. lactis* (apparently a plant strain) and *Str. faecalis* (an animal strain), and it is, of course, probable that both are derived from a common original plant strain. These adapted types as a rule grow well in milk and peptone media. On the other hand, the highly specialised animal parasites and those types found in milk products, and fermented plant material (including wines and beer) require special media. It is evident, therefore, that when plating for lactic acid bacteria, the types for which it is desired to search will influence the nature of the media employed. From a dairying aspect those types growing well in milk are of primary importance, but other types able to grow in bacterial association may be of significance, especially in faults and flavour production. It is necessary, therefore, to employ such media and conditions as will ensure a representative collection of those types present. The following media are recommended for the isolation of these:

Types sought	*Medium*	*Temperature of incubation*
Typical milk bacteria	Milk digest agar [1] (or yeast dextrose agar)	22° (30°), 45°
Ubiquitous types	Dextrose agar [1]	37°
Animal types (pathogens)	Blood agar [1]	37°
Plant types	Beer-wort agar [1]	22°, 45°

[1] The addition of autolysed yeast (0.5 per cent.) results in an improved medium giving faster growth and larger colonies. The addition renders the medium less selective, however.

Blood agar should be used if the presence of *haemolytic streptococci* of either animal or human origin is likely, as in udder samples of suspected cows. The appearance of the haemolytic zone is of some diagnostic value. If there is any doubt as to whether the colony is truly haemolytic, *i.e.* β-haemolytic, a transfer should be made into blood lemco-broth (lemco-broth + 5 per cent. sterile cow blood). β-haemolytic types produce a complete laking of the corpuscles in 24 to 48 hr. at 37°, whereas non-haemolytic and pseudo-haemolytic types do not. Blood agar is a fairly specific medium, as the typical milk bacteria grow with difficulty. The pathogenic streptococci grow vigorously in the poor-sugar medium, whereas those saprophytes growing in blood agar give appreciably better growth if sugar is added.

(For the preparation of milk digest agar and beer-wort agar, *see* Media, p. 672).

Practically all types grow well if double-poured plates are used. If the more rigidly anaerobic types such as *L. bifidus* are to be isolated, anaerobic or tall tube methods must be employed.

If it is desired merely to determine whether certain types are present, enrichment methods may be used. Such methods depend on the lethal effect of acid, alkali, oxygen, bile salt, etc., on certain groups. Available methods are summarised in Table LAB I

The use of selected media at selected temperatures as already described is, of course, to a limited extent an enrichment method.

Preparation of material. It is important to emulsify solid material. Grinding in a mortar followed by shaking with glass beads or proper emulsification should be employed.

Temperature of incubation. Thirty degrees C. is the best single temperature, as all types except the true thermophils will give some growth at this temperature. It is desirable, however, to incubate parallel plates at 22°, 37°, and 45°, as well as at 30° to 32°C. The temperature used will be governed largely by the nature of the work and the medium.

Period of incubation. This may be judged by the rate of growth of the colonies. As it is desired to pick off well-isolated colonies, plates at 22° should be incubated 7 to 10 days, those at 30° 5 to 7 days, 37° 3 to 4 days, and 45° 2 to 3 days. Shorter periods may result in picking off colonies attached to other microscopic colonies and in failure to obtain the slower growing types.

TABLE LAB I

Method	*Types depressed*	*Types increased*
Rapid transfers in milk, etc.	High acid, slowly growing streptococci, and lactobacilli	Low acid, fast-growing streptococci
Transfers in milk at clotting	Lactobacilli	Streptococci
Infrequent transfers in milk, etc.	Streptococci	Lactobacilli, specially Groups I and III, and Group III streptococci
Addition of 0·5 per cent. acetic acid to dextrose broth, and 0·5 to 1 per cent. lactic acid to milk	Streptococci	Lactobacilli
Streakings (aerobic)	Anaerobes (*L. bifidus*) and peroxide producers (Group II rods and cocci)	Non-respiring rods and cocci (Group I)
Media maintained at neutrality (*p*H 7)	Lactobacilli (most)	Streptococci
Addition of 5 per cent. NaCl	(*See* Orla-Jensen, LAB)	
Addition of bile salt	Non-intestinal types	Intestinal types (*Str. faecalis* and *L. acidophilus*)
Alkaline media (*p*H 9·6)	Streptococci other than intestinal group	*Str. faecalis* group
Addition of sodium lactate (4 per cent.)	Streptococci	Lactobacilli

Transfers to media. Plates having under 100 colonies are best. ***Whole*** colonies are transferred under a low-power binocular microscope to tubes of suitable media.

Plating medium	*Culture medium*
Milk digest or yeast dextrose agar	Chalk litmus milk
Dextrose agar	Chalk litmus milk
Blood agar	Chalk blood yeast dextrose litmus milk (or Robertson's cooked meat medium)
Beer-wort agar	Chalk beer-wort yeast litmus milk

The tubes are incubated at the same temperature as the plates until evident growth has taken place, *e.g.* milk is clotted. They are then recorded and held at room temperature until no longer required.

Selection of cultures. On removal from the incubator microscopic examinations are made. Usually cultures are " microscopically pure " and a preliminary grouping may then be made. Two further platings or streakings are, of course, advisable.

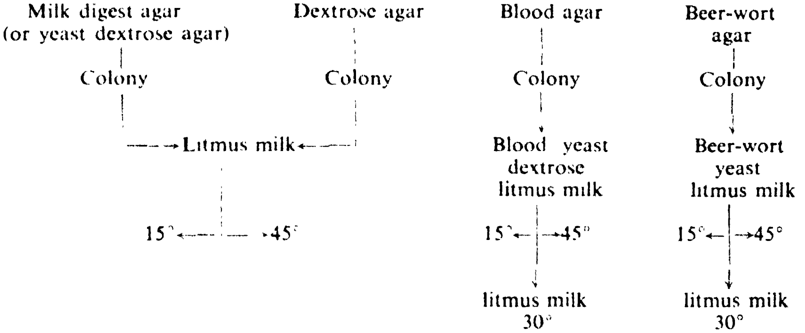
First separation into sub-groups. This may be conveniently done by ascertaining the temperature range of growth of the cultures. This information combined with a knowledge of the rate of growth in litmus milk, cell shape and arrangement is adequate for provisional classification, as shown in Tables LAB II to VI.

It must be emphasised, however, that no property is immutable and that a cast-iron procedure, similar to that of group fractionation in chemical analysis, is out of the question. Thus one cannot even say " *Str. lactis* invariably grows rapidly in milk." No one property is invariable. The confirmatory tests may result in strains being taken out of one sub-group into another.

Technique. Two tubes of the appropriate litmus milk medium are inoculated with a 0·1 per cent. inoculum from the same medium and incubated at 15° and 45°. (Slight variations *less* than 15° and *over* 45° are not important.) Either one or more loopfuls of known size or suitable saline dilutions may be used for this purpose. Cultures may be left about 4 days at 45° and 14 days at 15°, although strains which have been found to grow slowly in plain litmus milk at 30° naturally will not produce appreciable growth in 14 days at 15°.

If a special litmus milk is used (*i.e.* original colony from blood agar or beer-wort agar) a tube of plain litmus milk should also be inoculated and incubated at 30°.

Scheme.



Cultures are viable at room temperatures in England in chalk litmus milk media from about 3 months up to 1 year or more, depending on the particular type of lactic acid bacterium. The chalk does not mask the reaction in milk media unless growth is very slow.

Selection of cultures. The method of selection of cultures from the total number of isolations will depend on the object of the work. It may be required, for instance, to use statistical methods if a knowledge of distribution is required. On the other hand, the selection of one or two from each group is sufficient if only a knowledge of what types are present is required.

Purification of selected cultures. It is necessary to purify selected cultures before proceeding to final identification, and this is conveniently done by emulsifying a loopful of the milk culture in 9 ml. of saline and streaking a loopful of this emulsion on a plate of the original medium used for isolation. The type of colony should be recorded, especially on milk digest plates incubated at 45°.

Two such streakings, after the original isolation, may reasonably be assumed to ensure a pure culture. Anaerobic conditions must of course be provided if the more aerophobic species are under investigation. Anaerobiosis can with advantage be used for all types in Groups I to III, but is least necessary for Group I and advantageous for Group II.

It is probable that, if the original colony was a mixed one, the purification will result in the isolation of the more vigorous type. Hence streakings should be carefully examined for homogeneity.

Methods of identification. We may now consider the comparative value of the tests for identifying types or " species ".

These may be divided into three groups: (1) Characteristics suitable for routine classification. (2) Characteristics unsuitable for routine work. (3) Characteristics that tend to be variable or not sufficiently well-defined.

I. *Characteristics suitable for routine classification.* (1) Catalase test: (2) Cell shape and arrangement. (3) Colony type. (4) Temperature range of growth. (5) Types of growth in litmus milk, yeast dextrose litmus milk, blood litmus milk, and beer-wort yeast litmus milk. (6) Type of growth and final *p*H in dextrose broth. (7) Final acidities in milk. (8) Effect on blood agar. (9) Sugar fermentations.

(1) *Catalase test.* All the true lactic acid bacteria (Groups I to III) are catalase negative.

(2) *Morphological differences.* The morphology of a lactic acid bacterium is sufficiently constant to place it provisionally in one or more of the sub-groups (*see* Tables LAB II to VI).

In certain instances one species may be separated from another by morphology alone, *e.g. Str. lactis* and *Str. cremoris*, *L. bulgaricus* and *L. delbrücki*, provided that the cultures are examined under defined conditions of medium, age, etc. As a standardised procedure a milk culture at the time of clotting may be recommended, thus regulating the age physiologically rather than absolutely. Gram's stain may be recommended for this purpose.

(3) *Type of colony.* A study of surface colonies on yeast dextrose agar has demonstrated that only in a few cases is the type of colony of value in classification. *Str. cremoris* can frequently, but not always, be distinguished by its " rough " colony. The Group II rods, especially the milk strains, usually form very rough, flat colonies (" twisted coils of silk "). Group III rods tend to give dryish, raised colonies somewhat resembling *Corynebacterium.*

Group III streptococci may give large, moist, slimy colonies on plant extract media, especially if sucrose is present.

(4) *Temperature range of growth.* This property is one of the most useful and will have already been investigated by incubating cultures in litmus milk or reinforced litmus milk at 15° and 45°. For special purposes the additional temperatures of 10°, 22°, 55°, and 63° may be used. At temperatures of 15° or under and of 45° or over, media should be placed in the incubator overnight and inoculated the next day.

(5) *Types of growth in litmus milk, yeast dextrose litmus milk, blood litmus milk, and beer-wort yeast litmus milk.* All lactic acid bacteria grow in one or more of these media. Rod forms not growing in litmus milk may be presumed typical " plant " strains of Groups I, II, and III. Streptococci not growing in yeast dextrose litmus milk may be presumed to be the more fastidious pathogenic types and, similarly, lactobacilli to be the more fastidious wine and beer types. Blood and beer-wort respectively permit growth of these types.

(6) *Type of growth and final* pH *in dextrose broth.* This characteristic has been largely used in the differentiation of streptococci of human and bovine origin (Minett, 1935). The former usually produce a high *p*H (low acidity) and the latter a low *p*H (high acidity), *e.g. Str. pyogenes* (human) *p*H $> 5{\cdot}0$, *Str. agalactiae* *p*H 4·7 to 5·0 and saprophytic streptococci *p*H $< 4{\cdot}7$.

The type of growth (*e.g.* turbidity, nature of deposit) is also of importance for some types. In general, " non-chaining cells " give a marked turbidity with little or no deposit in the early growth stages, while " chaining types " give a deposit sometimes flocculent, and little or no turbidity. Thus *Str. lactis* gives a turbid medium and heavy deposit, while *Str. cremoris* yields only a slight deposit in yeast dextrose broth, the medium remaining clear. Sedimentation is also influenced by the nature of the medium, pH and salt concentration.

(7) *Final acidities in milk.* This test is extremely useful for separating the rod forms into Groups I (1·0 to 1·5 per cent. lactic acid), II (1·5 per cent. lactic acid), and III (1·0 per cent. lactic acid).

In practice, Group II rods produce such a high acidity that the bright pink colour attained in litmus milk enables them to be distinguished readily from the members of the other groups.

(8) *Effect on blood agar* (*haemolysis*). The behaviour of the lactic acid bacteria on blood agar must be regarded similarly to the sugar fermentations. Both types of phenomena are extremely sensitive to the conditions of the tests, which should therefore be rigorously standardised. Those types of haemolysis described by Brown as α and β are sufficiently well defined and constant to be of value. All other types, such as " bleaching " (or weak β), " alpha prime ", and " greening ", have been found to vary so much that their diagnostic value is nil.

The typical milk lactic acid bacteria grow poorly on blood-agar plates, even when yeast is added.

(9) *Sugar fermentations.* Experience with these bacteria demonstrates beyond doubt that sugar fermentations may be unreliable and cannot be used in a rigid manner for classification purposes. Different substances such as peptones, casein digests. and yeast extract may give widely varying results, indeed the typical milk bacteria such as *Str. cremoris* and *L. bulgaricus* may be unable to ferment even dextrose with some peptones as a source of nitrogen. Generally speaking, the behaviour of a micro-organism is a result of its previous history. In conformance with this principle the lactic acid bacteria may be divided into three groups on sugar fermentations alone—the " milk ", " animal ", and " plant " types. The adaptation of the member of one group to multiply in a " foreign " medium is frequently shown by the acquirement of the ability to ferment certain sugars more readily, *e.g.* the lactose-fermenting variety of *L. delbrücki* and also *L. casei.*

For identification purposes sugar fermentations are of use (i) to confirm the results of other tests, and (ii) to separate closely allied species. It may be recommended that while a positive result is of significance, a negative result should be regarded with considerable caution. Strains may easily lose the power to ferment particular sugars.

II. ***Characteristics unsuitable for routine classification.*** (1) Proportion and identification of metabolic end-products. (2) Optical activity of lactic acid produced. (3) Complete study of sugar fermentations. (4) Complete study of respiration mechanisms. (5) Thermal death points.

These characteristics are unquestionably as important as any others for identification work. The first four have the disadvantage, however, that in order to determine them the bacteriologist requires a team of chemists.

III. ***Characteristics that tend to be variable or not sufficiently defined.*** (1) Peptonisation of casein. (2) Morphology (for species differentiation generally). (3) Fermentation of *specific* sugars. (4) Rate of growth in milk. (5) Gas production. (6) Acetoin production. (7) " Haemolysis " phenomena in blood agar (other than α- and β-haemolysis).

Variable characteristics. (1) *Peptonisation of casein. Str. liquefactions* is readily distinguished by its rapid peptonisation in litmus milk, but apart from this instance the proteolytic power is of no diagnostic value.

Haemolytic streptococci that have been kept in milk media for some time may acquire the power of peptonising casein, due presumably to self-adaptation to a new nitrogen source. Old cultures of lactic acid bacteria in chalk milk media frequently peptonise the milk.

(2) and (3) have already been discussed.

(4) *Rate of growth in milk.* Types such as *Str. lactis* and *L. bulgaricus* have been found in laboratory culture sometimes to become weakened and ultimately fail to grow in milk. This may be due to loss of ability to ferment lactose or to utilise casein. *Str. bovis* has been found difficult to grow in milk. *L. bifidus* fails to grow in milk on isolation unless the medium is de-aerated.

(5) *Gas production.* Practically all strains that form gas when freshly isolated lose this power on cultivation.

(6) *Acetoin production.* Most of the lactic acid bacteria have been found to give very variable results when tested for the Voges-Proskauer reaction.

Type cultures were tested in yeast dextrose broth and citrate yeast dextrose broth. With one exception, either none or negligible amounts of acetoin were produced.

Variability in the behaviour of the lactic acid bacteria. It has been already suggested that the typical milk lactic acid bacteria may be regarded as artificially produced types of comparatively recent origin. By analogy the typical beer, wine, and vegetable mash bacteria may fall into the same category. It is possibly due to this that constancy of behaviour is the exception rather than the rule. There are obviously two main causes for variation in a freshly isolated strain: (i) The variation is a process of adaptation to new conditions (artificial media, etc.). (ii) The source from which it was isolated was not its true habitat, with the result that in a new environment it rapidly loses its recently acquired characteristics, *e.g.* old stock cultures of *Str. lactis* sometimes grow poorly in milk.

It is generally recognised by bacteriologists that strains freshly isolated behave differently from those that have been kept on artificial media for some time.

TABLE LAB II

DETERMINATION OF OPTIMUM TEMPERATURE (°C)

Type	*Growth in plain litmus milk*	*Growth at*		*Optimum temperature*
		15°	45°	
Streptococcus . . .	+	+	0	30°
,, . . .	+	0	0	37°
,, . . .	0	+	0	22°
,, . . .	+	+	+	37°
,, . . .	+	0	+	45°
Lactobacillus . . .	+	+	0	30°
,, . . .	0	+	0	22°
,, . . .	+	+	+	37°
,, . . .	+	0	+	37°-45°
,, . . .	0	0	+	37°-45°

It may be emphasised that although a type may be constantly found in a certain habitat, it does not follow that this is the true or original habitat of the organism. Thus *Str. bovis* is the common streptococcus of cow faeces. In character, however, *Str. bovis* resembles the plant strains rather than *Str. faecalis*. Its presence may therefore be attributed to the herbivorous nature of the cow. *Str. lactis* presents another interesting problem. Practically never found in the udder, it is yet the " common organism of souring milk ".

Classification into types or " species ". The following characteristics are suggested to be the most suitable for " species " identification : (1) Fermentation of selected sugars. (2) Final acidities in milk and final *p*H values in dextrose broth.

In the event of the results obtained by these methods giving no clear-cut indication the following additional properties may be investigated : (3) Heat resistance (15 min. at 60°). (4) Growth in bile salt lactose broth (*see* Tables LAB VII to XI).

Standard technique. Transfer 1 ml. of a viable culture in litmus milk (or special litmus milk) to 9 ml. of saline and emulsify thoroughly. Use 0·1 ml. quantities for inocula. (A calibrated 1 ml. pipette is convenient.) Incubate test media for 21 days at 22°, 14 days at 30°, 10 days at 37°, or 7 days at 45°. (For optimum temperature *see* Table LAB II.) Record growths and sugar acidities after 3 and 14 days at 30° and *pro rata* at the other temperatures.

Methods. (1) ***Sugar fermentations.*** The nitrogen source should, strictly speaking, be that most suitable for the strain in question. There are thus two alternatives : (*a*) to find the best source for each strain, and (*b*) to standardise a source. Of these (*a*) is obviously impracticable. Probably the best all-round source would be the yeast casein double digest (*see* Media), but this has not been used yet for typing purposes.

The data used, therefore, have been obtained by combining the results obtained by Orla-Jensen with those obtained by the author at Shinfield.

The sugar broths consist of : 1 per cent. peptone * ; 0·5 per cent. NaCl (block salt) ; 0·5 per cent. test sugar, in distilled water (good tap water may be used), *p*H 6·8. Sterilise by three steamings for ½ hr.

Selected sugars. For *streptococci :* Dextrose,[1] mannitol, arabinose, sucrose, maltose, raffinose, salicin, and aesculin (eight sugars). For *lactobacilli :* Dextrose,[1] lactose, sucrose, maltose, raffinose, salicin, aesculin (seven sugars).

Fermentation tubes should be inserted in the test-tubes, not because gas may be liberated (no strains have been found forming gas under the prescribed conditions), but because this is a simple way of providing aerobic and " anaerobic " conditions in one tube.

A set of standards should be prepared containing 0·05, 0·1, 0·2, and 0·5 per cent. lactic acid and a trace of $HgCl_2$ (B.P. lactic acid is 85 to 90 per cent.). Acidities of less than 0·05 per cent. are considered to be 0 (negative), and of 0·1 per cent. or higher as + (positive), those of 0·05 to 0·09 per cent. as W (weak).

Slight acidities (< 0·05 per cent.) in these tubes are ignored because: (1) Sugars are in practice never pure ; (2) " Peptone " and other nitrogen sources may contain traces of sugar ; (3) sterilising converts some sugars partly to others ; and (4) amino acids, etc., may be deaminated to give organic acids.

(2) (*a*) *Final acidities in milk.* Ten ml. of a bulk milk, separated and tubed in 6 × ⅝-in. tubes, and then sterilised by steaming, may be used for the final acidity test. The whole of the medium is titrated with $\frac{N}{9}$ NaOH. A little distilled water may be used for washing out the tube into the titration flask. Add 1 ml. 0·5 per cent. phenolphthalein in 50 per cent. alcohol.

N.B.—Titrated acidity = acidity of medium + acid formed.

(*b*) *Final p*H *in dextrose broth.* Medium : 1 per cent. peptone ; 1 per cent. lemco ; 0·5 per cent. NaCl (block salt) ; 2 per cent. dextrose ; distilled water ; *p*H 6·8. Sterilise by three steamings.

Estimate final *p*H in a B.D.H. comparator, using bromcresol green or bromphenol blue, or by a pH meter and glass electrode.

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* Commercial peptones vary considerably in their growth-promoting power for lactic acid bacteria. The most suitable found by trial should be used. A very small amount of simple yeast autolysate (*see* Media) may be added with advantage.

[1] Dextrose is included as a " control ".

(3) *Heat resistance.* Add the standard inoculum to 10 ml. of litmus milk (or special litmus milk), mix thoroughly, immerse the tubes as far as possible in a water bath at 60° to 65° C. Use a control tube with thermometer and maintain for 15 min. after reaching 60°. Cool in cold water to 30°, then incubate.

(4) *Bile salt lactose.* Medium: 2 per cent. peptone; 0·5 per cent. lactose; 0·5 per cent. sodium tauroglycocholate; distilled or good tap water, *p*H 6·8.

Maintenance of Cultures. The increasing use of cultures of lactic acid bacteria (streptococci and lactobacilli) in the industry, not only as starters for cheese and buttermaking but also for fermented milks and other purposes, makes the maintenance of such cultures in a state of purity and vitality a matter of considerable commercial importance. The following observations and hints may be of use to dairy bacteriologists and others engaged in propagating these cultures.

Cultures may be obtained: (i) From firms and centres selling starter cultures (primarily dairying). (ii) From the National Collection of Type Cultures (address for dairy cultures: N.I.R.D., Shinfield, Reading, Berks. (iii) From individual bacteriologists. (iv) By isolation from natural sources.

From a practical point of view, sources (ii), (iii), and (iv) are available only to experienced bacteriologists, and the non-specialist in the industry has to rely on commercial sources. The most satisfactory source for those who have the time and knowledge is (iv).

Isolation. The common habitats of starter organisms are: (i) Commercial starters—nearly always a mixed culture, and after use in the dairy possibly contaminated. (ii) Soured milks. (iii) Cheese whey and young cheese. (iv) Buttermilk from ripened cream butter.

The easiest way of isolating pure cultures (or single strains) is by a combination of (*a*) enrichment, and (*b*) streaking or plating. Enrichment may be defined as growing the organisms in a favourable medium under favourable conditions, thereby encouraging the maximum proliferation of the desired organism and the "swamping" of unwanted bacteria. For ordinary lactic streptococci (*Str. lactis* and *Str. cremoris*) growth in tubes or flasks of milk at about 30° C. is a suitable method of enrichment. Transfers may be made through a few flasks of this medium before streaking or plating on a suitable solid medium. The following media may be recommended for this purpose: (i) Milk agar. (ii) Yeastrel agar. (iii) Milk serum agar. (iv) Yeast dextrose agar. (v) Peptic milk digest agar (for streptococci). (vi) Pancreatic milk digest agar (for lactobacilli). (vii) Various plant extract agars.

After plates have been poured and allowed to harden, a loopful of the enriched milk culture is emulsified in a tube of sterile water or Ringer solution and a loopful of this streaked several times across the agar plate. If ordinary plating is preferred, the following scheme permits the obtaining of approximately 200 colonies on the plate: Add 1 loopful of the milk culture to 9 ml. of Ringer, transfer 1 ml. of this to a second tube of Ringer, then 1 loopful of this second dilution will produce about 200 colonies in a plate. It is preferable to hold the plate under anaerobic or "micro-aerophilic" conditions. The latter may be obtained by pouring a second layer of medium on to the first containing the organisms. Always incubate 5 days at 30 C. or 3 days at 37° C. to permit slow-growing organisms to form colonies. At the end of this time examine the plate under a low-power microscope or powerful lens and mark a typical well-isolated colony. Pick this off with a loop into a tube of litmus milk or yeast dextrose litmus milk. After three such streakings or platings the culture may be assumed to be pure.

Routine maintenance of type cultures. The essential points to bear in mind are purity and vitality. As, from the dairy point of view, vitality means the rate of growth and acid production in milk, the usual way of achieving these objects is to make daily transfers in autoclaved milk. When it is desired to maintain a large number of cultures, any of which may be wanted at any time, this system becomes unmanageable and very expensive. A modified method has to be adopted, therefore, which involves less frequent transfer in media designed to minimise the toxic effect of end-products of metabolism. For the lactic acid bacteria the acidity developed in milk, which is about 1 per cent. for the streptococci and 1·5 to 2·5 per cent. for the lactobacilli, is by far the most important. Oxygen also has a weakening effect on some types.

Choice of media. There are two ways of reducing the lethal effect of acid: (*a*) by the inclusion of a neutralising agent such as chalk, and (*b*) by using only a small percentage of sugar, impossible, of course, in milk. Thus one can use either milk media to which 3 per cent. chalk has been added, or broths or agar media containing only from 0·1 to 0·2 per cent. sugar. Five very useful media are: (i) Plain litmus milk + 3 per cent. chalk. (ii) Yeast dextrose litmus milk + 3 per cent. chalk. (iii) Yeastrel agar or milk agar (containing about 0·05 per cent. lactose). (iv) Yeast dextrose agar (0·3 per cent. peptone, 0·3 per cent. lemco, 0·3 per cent. yeastrel, 0·2 per cent. dextrose, 1·5 per cent. agar—*p*H 6·8) (for the heterofermentive aroma streptococci 2 per cent. beer-wort may be used in place of 0·2 per cent. dextrose). (v) Robertson's cooked meat medium.

Some batches of chalk contain very heat-resistant spores. It is essential that the spores be killed before the chalk is used for media. The whole problem of sterilising chalk, as of any other material, is to raise the temperature of the spores up to the nominal temperature of the oven or autoclave, *i.e.* a question of conductivity of the material. There are two golden rules to be followed in this respect: (*a*) always sterilise wet if possible, and (*b*) sterilise in small quantities. Heating dry chalk in the hot-air oven at 160° C. for 2 hr. is quite useless; indeed, we have known spores to survive in chalk after nominal treatment for 3 days at 200° C. A superior method is to heat the chalk *wet* in small quantities in test-tubes or flasks for ½ hr. at two atmospheres (134° C.).

Solid media have the important advantage that the cotton-wool plug or cap liner cannot become wetted, and the tubes can be laid flat. Stab cultures should, of course, always be used. A disadvantage is that it is not always possible to tell if a delicate organism has grown.

Milk media have the important advantage that the characteristic reactions of the type in litmus milk can be seen at a glance, and, in the case of the types that reduce litmus, the presence of reduced litmus can be taken as a reasonably certain sign that the culture is alive. *See* Media.

For the advantages of screw-capped McCartney bottles *see* Davis (1939), *DI*, **4**, 331, 360. Rubber liners to the caps which can be sterilised separately are recommended. Lactic acid bacteria remain viable in chalk litmus milk longer in screw-capped bottles than in plugged test-tubes.

Technique of sub-culture. If large numbers of cultures in milk are sub-cultured by pipette, the cost is high. The use of a large loop is cheaper and safer, as the loop can be sterilised by the operator, whereas it is possible for unsterile pipettes to slip through. The same advantage applies to the use of wire for stab cultures.

As a general routine, once a month is sufficient to transfer cultures provided they are removed from the incubator as soon as growth is evident. The temperature of incubation should be near the optimum for the organism, as given below:

	° *C.*
Str. cremoris, lactis, faecalis	30 to 35
Str. thermophilus	45
Heterofermentive streptococci	25 to 30
L. casei, plantarum	35 to 40
L. bulgaricus, jughurt, helveticus, lactis	45 to 50
L. acidophilus	35 to 40
Heterofermentive lactobacilli	20 to 25

TABLE LAB III—STREPTOCOCCI (I and II)

Cell shape and arrangement	*Growth in plain litmus milk at 30° C*	*Surface growth*	*Growth at 15°*	*Growth at 45°*	*Temperature range of growth (average)*	*Types (For synonyms, see Davis, 1944)*
Oval diplococci . .	V rapid—reduces litmus before clotting milk	Good	+	—	10° to 40°	*Str lactis*
,, ,, . .	,, ,, ,, ,, ,, ,,	Good	+	+	10° to 48°	*Str. faecalis*
Chains of varying length and diplococci .	V rapid—reduces litmus before clotting milk	Good	+	+	10° to 48°	*Str. liquefaciens* (peptonises milk)
,, ,, ,, ,,	Fair—reduces litmus before clotting milk	Good	+	+	10° to 46°	*Str glycerinaceus*
,, ,, ,, ,,	Moderate or slow, Litmus not reduced before clotting	Fair	+	∓	10° to 40	*Str. inulinaceus*
,, ,, ,, ,,	,, ,, ,, ,, ,, ,,	Fair	—	—	25° to 37°	*Str. bovis*
Chains of varying length	Moderate—litmus not reduced before clotting	Poor	—	+	20° to 50°	*Str. thermophilus*
,, ,, ,, .	Rapid—litmus reduced before clotting	Poor	+	—	10° to 36°	*Str cremoris*
, ,, ,, .	Moderate—litmus not reduced before clotting	Poor	–	—	20° to 39°	*Str. agalactiae* *Str pyogenes* (bovine)
. ,, ,,	Variable—litmus not reduced before clotting	Poor	∓	±	V	*Str pyogenes* (human)

TABLE LAB IV—STREPTOCOCCI (III)

(All grow at 15° but not at 45°)

Cell shape and arrangement	*Growth in plain litmus milk*	*Growth in yeast dextrose or beer-wort yeast litmus milk*	*Temperature range of growth (average)*	*Types*
Rather small cells	Poor	Good	5° to 37°	*Str. mesenteroides*
Chains of varying length	Poor	Good	10 to 36°	*Str dextranicus*
,, ,, ,,	Poor	Good	10 to 36° (?)	*Str citrovorus*
Diplococci .	V good—litmus reduced—gas formed	V good	5° to 40°	*Str diaceti-lactis*

TABLE LAB V—LACTOBACILLI (I and II)

Cell shape and arrangement	*Growth in plain litmus milk*	*Growth in yeast dextrose or beer-wort yeast litmus milk*	*Surface Growth*	*Growth at 15°*	*Growth at 45°*	*Temperature range of growth (average)*	*Type*
Long straight-sided rods in chains . . .	Good—litmus reduced strongly after clotting	Good	Good	+	—	15° to 39°	*L. casei*
Short rounded rods, singly and pairs . . .	V. slow—litmus not strongly reduced	Good	Good	+	—	15° to 38°	*L. plantarum*
Long thin beaded rods in chains . . .	V. good—litmus reduced (litmus *very* acid)	Good	Scanty	—	+	23° to 51°	*L. helveticum*
,, ,, ,,	V. good—litmus reduced (litmus *very* acid)	Good	Scanty	—	+		*L. jughurt*
,, ,, ,,	V. good—litmus reduced (litmus not *very* acid)	Good	Scanty	—	+	23° to 53°	*L. bulgaricus*
,, ,, ,,	(Litmus not *very* acid) litmus reduced	Good	Scanty	—	+	22° to 51°	*L. lactis*
Short rounded rods, singly and pairs . . .	Variable—litmus reduced if good growth	Good	Scanty	—	+	23° to 54°	*L. Delbrücki*
,, ,, ,,	V. good—litmus reduced	Good	Fair	(?)	+	20° to 48°	*L. acidophilus*
Medium-sized rods . .	Slight acidity—milk not clotted or litmus reduced	As in litmus milk	Scanty	—	+	30° to 65°	*L. thermophilus*

TABLE LAB VI—LACTOBACILLI (III)

(All grow poorly in plain litmus milk and well in yeast dextrose or beer-wort yeast litmus milk)

Cell shape and arrangement	*Growth at 15°*	*Growth at 45°*	*Temperature range of growth (average)*	*Type*
Short rods, mostly singly	—	—	20° to 37°	*L. pentoaceticus*
Long or medium rods, tendency to chains .	—	+	18° to 45°	*L. fermenti*
Variable	+	—(?)	10° to 37° (?)	*L. pastorianus*

TABLE LAB VII

Streptococci (Groups I and II)

Type	*Mannitol*	*Arabinose*	*Dextrose*	*Sucrose*	*Maltose*	*Raffinose*	*Salicin*	*Aesculin*		*Final acidity in milk. % lactic acid*	*Type of growth in dextrose broth (48 hr.)*		*Final* pH *in dextrose broth*	*Heat resistance (15 min. at 60°)*	*Growth in bile salt lactose*
								Acid	*FeCl$_3$*		*Turbidity*	*Sediment*			
Lactis . .	±	∓	+	0	+	0	+	+	+	C. 0·8	+ +	+	C. 4·3	+	±
Faecalis . .	+	∓	+	±	+	0	+	+	+	C. 0·6	+ +	+	C. 4·3	+	+
Liquefaciens .	+	0	+	+	+	0	+	+	+	C. 0·7	+	+	C. 4·3	+	+
Glycerinaceus .	+	0	+	+	+	0	+	+	+	C. 0·5	+	+	C. 4·4	+	+
Inulinaceus .	±	0	+	+	+	V	+	0	0	C. 0·5	+	+	C. 4·3	0	+
Bovis . .	0	±	+	+	+	0	+			C. 0·6	+	+	C. 4·7	+	+
Thermophilus .	0	0	+	0	0	0	0	0	0	C. 0·6	0	+		+	0
Cremoris . .	0	0	V[1]	0	0	0		+[1]		C. 0·7	0	+		+	0
Agalactiae . .	0	Serum added to sugar broths	+	+	+	0	+	0		C. 0 5	0	+	C. 4·7	0 (30′ at 60° C.)	0
Dysgalactiae .	0		+	+	+	0	0	0		C. 0·5	V	+[2]	C. 5·0	0 (30′ at 60° C.)	0
Uberis . .	+		+	+	+	0	+	+		C. 0·5	V		4·7-4·9	0 (30′ at 60° C.)	0
Pyogenes (bovine)	0		+				+	0		C. 0·5	V	+[2]	5·0-5·2		(?)
Pyogenes (human)	0	0	+	+	+	0	+	±	±	V	V	+[2]	V	0	±

[1] Practically no growth with some peptones.
± = mostly +, ∓ = mostly −. C. = about.

[2] Two per cent. serum added.
V = variable.

TABLE LAB VIII—Streptococci (Groups I and II)

(Additional Characteristics)

Lactis	Pentose fermentation sometimes lost in sub-culture. Forms chains at low temperatures and in broth.
Faecalis	Ubiquitous and able to grow over a wide range of conditions.
Liquefaciens	Vigorously growing species—ferments most sugars. Only true lactic acid organism rapidly peptonising milk.
Glycerinaceus	Ferments most sugars.
Inulinaceus	*Cf. Str. uberis.*
Bovis	Most common streptococcus in cow dung. Characteristics change on sub-culture.
Thermophilus	Common in milk held at 40° to 50°. Difficult to grow on non-milk media.
Cremoris	Difficult to grow on non-milk media. Makes milk slimy at low temperatures sometimes.
Agalactiae	Mostly long chains, large cells. Non-haemolytic or narrow zoned. Meth. blue milk (1 : 20,000) not reduced. Sorbitol O, Trehalose +.
Dysgalactiae	Medium chains, small cells. Inulin O, sod. hippurate —. Meth. blue milk (1 : 20,000) reduced.
Uberis	Short chains, cells small. Slight growth in litmus milk at 15°. Inulin +. Meth. blue milk (1 : 20,000) reduced.
Pyogenes (bovine)	Well-defined β-haemolysis. Sod. hippurate O, sorbitol +, trehalose O.
Pyogenes (human)	Well-defined β-haemolysis. Hippurate O, sorbitol O, trehalose +.

TABLE LAB IX—Streptococci (Group III)

Type	*Man-nitol*	*Ara-binose*	*Dex-trose*	*Suc-rose*	*Mal-tose*	*Raf-finose*	*Salicin*	*Aesculin*		*Final Acidity in milk. % lactic acid*	*Type of growth in dextrose broth (48 hr.)*		*Final* pH *in dextrose broth*	*Heat resistance (15′ at 60° C.)*	*Growth in bile salt lactose*
								Acid	*FeCl$_3$*		*Turbid-ity*	*Sedi-ment*			
Str. mesenteroides	±	+	+	+	+	±	±	+	+[1]	V			V	+	±
Str. dextranicus	0	0	+	+	+	±	0	0	+	V			V	±	0
St. citrovorus	0	0	+	0	0	0	0	0	0	V			V		0 (?)
Str. diaceti-lactis	0	+	+	0	+	0	+			C. 0·8	+ +	+		+	+

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[1] Frequently gives black colour without addition of FeCl$_3$.

TABLE LAB X—LACTOBACILLI (GROUPS I AND II)

Type	*Dextrose*	*Lactose*	*Sucrose*	*Maltose*	*Raffinose*	*Salicin*	*Aesculin*		*Final acidity in milk. % lactic acid*	*Type of growth in dextrose broth (48 hr.)*		*Final* pH *in dextrose broth*	*Heat resistance (15′ at 60°)*	*Growth in bile salt lactose*
							Acid	*FeCl₃*		*Turbidity*	*Sediment*			
L. casei	+	+	+	+	0	+	+	—	0·7-1·6	+	+	< 4·3 (4 days)	+	+
L. plantarum	+	+	±	+	∓	±	+	+	0-1·6	+	+	> 4·3 (4 days)	+	±
L. helveticum	+	+	0	+	0	0	0	0	2·0-2·8	Little or no turbidity			+	+ (?)
L. jughurt	+[1]	+[1]	0	0	0	0	0	0	2·0-2·7	,,	,,		+	+ (?)
L. bulgaricus	+[1]	+[1]	0	0	0	0	0	0	C. 1·6	,,	,,		+	0
L. lactis	+	+	+	+	—	+	∓	±	1 0-1·6	,,	,,		+	+
L. Delbrücki	—	V	+	+	0	0	0	0	V	,,	,,		+	∓
L. acidophilus	+	+	±	—	∓			—	High	,,	,,		+	+
L. thermophilus	+[1]	+[1]	—[1]	0	0	0	0		C. 0·25	0	+	5·4	+	

[1] Practically no growth with ordinary peptone. Fermentations as reported in literature.

TABLE LAB XI—LACTOBACILLI (GROUP III)

Type	*Dextrose*	*Lactose*	*Sucrose*	*Maltose*	*Raffinose*	*Salicin*	*Aesculin*		*Behaviour in milk*	*Heat resistance (15′ at 60°)*	*Growth in bile salt lactose*
							Acid	*FeCl₃*			
L. pentoaceticus	+	+	0	+	0	0	0	0	Growth very slow	+	0
L. fermenti	+	+	+	+	+	0	0	0		+	0
L. pastorianus	+	0	0	0	0	0	0	0	,,		0

± = mostly +. ∓ = mostly —.

It is recommended that *Str. thermophilus* and the high-temperature lactobacilli be sub-cultured once a week. Cultures should be held at 10° to 15° C. between transfers, but not lower; refrigeration may result in a serious loss of vitality. The faecal streptococci are extremely viable, lasting for over a year on agar slopes at room temperature.

If monthly transfer is impossible, drying in serum may be used.

Normally, it is advisable to keep at least the last two, preferably three, transfers of each culture. *See* Freeze drying.

Contaminations. The two commonest contaminants are spore-formers and moulds. The former are usually due to highly resistant spores in chalk or peptone. The intermittent steaming method is sufficient to sterilise milk alone, but if peptone, etc., is added it is most unreliable, and a short or momentary autoclaving is advisable. Chalk should *always* be sterilised separately before use, in addition to the sterilisation in the medium.

Mould contamination is usually due to wetting of the plug by liquid media, *i.e.* carelessness in technique. In addition, cork liners of McCartney bottles are liable to grow moulds, and this is why rubber liners are preferred.

The most serious contamination is that due to salivary droplets, as these may contain streptococci that cannot always be differentiated easily from the original culture. This is yet another reason why platinum loops are preferable to pipettes. Further, saliva may be a source of phage. Particular care must be taken to avoid blowing out burning plugs when one tube is still open; it is *always* better to use the hand for this purpose. The burning of plugs is best avoided.

All workers maintaining type cultures of lactic acid bacteria are strongly recommended to test their cultures regularly as follows:

Add 1 ml. *c.* 10 vol. hydrogen peroxide to a milk tube culture, shake and stand 1 min. If a froth forms the culture is contaminated. This test is very simple and should be widely known by dairy bacteriologists.

Agar stab cultures may be tested similarly, a steady evolution of bubbles being an indication of contamination. Heavy surface growth is also a reasonably certain sign of contamination.

Contaminated cultures should be removed at once from other cultures. As all common bacteria except the lactic acid bacteria are catalase-positive, this test will detect all forms of contamination except that by streptococci.

It is often possible to go back to an earlier culture that is not contaminated. If not, a fresh culture may be obtained. Sometimes, however, this is also impossible, or the culture in question is behaving well, or giving a good aroma, and it is particularly wanted pure again. It is essential in these circumstances to purify the culture by enrichment methods and/or plating and picking off colonies. Practically all contaminants are aerobes or facultative anaerobes, and if the contamination is a slight one, *e.g.* a trace of mould growth, it is often possible to purify the culture by rapid transfer in a suitable medium under anaerobic conditions, *e.g.* in a McIntosh and Fildes jar, or more simply by adding a 1-in. layer of sterilised liquid paraffin or a ½-in. layer of sterilised vaseline to the culture medium. Three such transfers will usually free cultures from moulds, but spore-formers are usually difficult to deal with and it is advisable to plate or streak the culture at once and incubate anaerobically. Typical colonies are then picked off into tubes of a suitable medium and rapid transfers made. A second plating or streaking is always advisable. If plating is impracticable, rapid transfers at the optimum temperature and in a selective medium under "anaerobic" conditions are the best one can do.

If a culture is contaminated only at the surface, a useful technique is to sterilise the outside of the tube with burning alcohol and then to break the tube in a sterile Petri dish, and reinoculate with a wire from the bottom of the culture. This device may be used both for agar stab and *clotted* milk cultures.

A common experience is to find that a stab culture has failed to grow. The first thing to do then is to pour aseptically a reinforced milk medium on to the *old* stab culture and incubate. This method often recovers the organism.

General hints. (1) Continued culture in any one medium often results in alteration of the characteristics of the organism, and sometimes in loss of vitality. It is good, therefore, to change the medium sometimes. A simple method is to alternate chalk litmus milk with ordinary milk agar or yeastrel agar. The following procedure may be adopted :

Make a first stab culture in milk agar. After one month prepare a second culture as follows : Shake vigorously a tube of chalk litmus milk and pour aseptically on to the old stab culture. Incubate until the litmus reddens or shows signs of reduction and then hold at 10° to 15° C. for a month. At the end of this time make a further stab culture, and so on. This is very quick and simple and saves relabelling every second month.

(2) Wire racks are convenient for incubating and storing cultures. The tubes should be protected by a brown paper dust cover.

(3) Use an inoculum of 1 to 5 per cent. if possible.

(4) The following characteristics are most useful for checking trueness to type : (*a*) Microscopic examination (Gram stain on milk culture). (*b*) Absence of catalase and of marked surface growth. (*c*) Reactions in litmus milk, etc. (*d*) Growth at different temperatures. (*e*) Heat resistance. (*f*) Fermentation of specific sugars.

THE DIFFERENTIATION OF SIMILAR TYPES OF LACTIC ACID BACTERIA. Dairy bacteriologists may find difficulty in identifying some types of lactic acid bacteria, *e.g.* in starter, on account of their similarity. Such types have been grouped in pairs, as usually it is relatively easy to narrow down the possibility to one or two types. Under each type are given simple reactions which can be used to differentiate one from the other. These have been chosen by experience as being the most consistent and easy to apply. It should be realised that reactions in bacteriological work are rarely 100 per cent. valid and that exceptions may be fairly frequent. Too much importance should not, therefore, be attached to single tests. Especially is this the case with sugar fermentations.

Types which are highly characteristic, *e.g. L. thermophilus*, have not been included.

STREPTOCOCCUS I AND II

Str. Lactis	*Str. Cremoris*
Diplococci in milk (*a*).	Chains in milk.
Marked turbidity in dextrose broth in 24 hr. at 37° C. (*b*).	Slight or no turbidity in dextrose broth.
Ferments maltose, dextrin, and trehalose (*c*).	Usually does not ferment these sugars.
Grows at 40° (*d*).	No growth at 40° C.
Good growth without milk (*e*).	Growth without milk scanty or nil.
Grows in 4 per cent. NaCl broth (*f*).	No growth in 4 per cent. NaCl.
Grows at *p*H 9·2 (*g*).	No growth at *p*H 9·2.
Grows in 2 per cent. sodium lactate broth (*f*).	No growth in 2 per cent. lactate broth.

Str. Agalactiae	*Str. Bovis*
Marked hydrolysis of hippurate (*h*).	Slight or no hydrolysis.
Does not ferment starch.	Ferments starch.
Usually orange deposit in starch broth (*j*).	No orange deposit.
Killed in 30 min. at 60° C. (*k*).	Survives 30 min. at 60° C.
Grows in crystal violet (1 in 500,000) media.	Usually no growth in crystal violet media.

Str. Bovis	*Str. Inulinaceus* [1]
No growth at 15° C.	Grows well at 15° C.
Slight or slow reduction of litmus (*l*).	Rapid reduction in litmus milk.
Does not ferment mannitol or inulin.	Ferments mannitol and inulin.
Strong starch fermentation.	Slight starch fermentation.
Survives 30 min. at 60° C.	Killed in 30 min. at 60° C.
Str. Bovis	*Str. Faecalis*
No growth at 15° C.	Grows well at 15° C.
Never ferments sorbitol or mannitol.	Ferments mannitol and sorbitol.
Always ferments starch and raffinose.	Never ferments starch or raffinose.
Str. Lactis	*Str. Faecalis*
Does not ferment sorbitol.	Ferments sorbitol.
Usually does not ferment sucrose and mannitol strongly.	Ferments sucrose and mannitol strongly.
No metabolic production of diacetyl, etc. (*m*).	Metabolic production of diacetyl, etc.
Growth at 45° C. nil or slight.	Grows well at 45° C.
Killed by 30 min. at 65° C.	Resists 30 min. at 65° C.
No growth at *p*H 9·6.	Grows at *p*H 9·6.
No growth in 6·5 per cent. NaCl.	Grows in 6·5 per cent. NaCl.
Poor growth without sugar (*n*).	Grows well in non-sugar media.
Str. Faecalis	*Str. Glycerinaceus* [2]
Ferments arabinose.	Does not ferment arabinose.
Does not ferment glycerine.	Ferments glycerine.
Str. Faecalis.	*Str. Thermophilus*
Grows at 15° C.	No growth at 15° C.
Good growth without milk.	Poor growth without milk.
Marked reduction in litmus milk before clotting.	Slight or no reduction in litmus milk.
Str. Dysgalactiae	*Str. Uberis*
(Group II (Minett) mastitis streptococci.)	(Group III (Minett) mastitis streptococci.)
Does not grow well at 15° C.	Grows well at 15° C. and (slightly) at 10° C.
Does not ferment mannitol, salicin, aesculin, inulin, and starch.	Ferments these sugars.
Does not hydrolyse hippurate.	Hydrolyses hippurate.
Not inhibited by crystal violet and sodium azide (*o*).	Usually inhibited by crystal violet (1 in 500,000) and sodium azide (0·03 %).
Str. Uberis	*Str. Lactis*
(Group III (Minett) mastitis streptococci.)	
Ferments inulin and starch.	Does not ferment these sugars.
Does not reduce Janus green.	Reduces Janus green.
Good or moderate growth in milk.	Very rapid growth in milk.
Does not resist 30 min. at 60° C.	Resists 30 min. at 60° C.

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[1] Many bacteriologists regard this as a variant of *Str. bovis*.

[2] *Str. glycerinaceus* is sometimes regarded as a glycerol-fermenting variant of *Str. faecalis*.

Str. Uberis	*Str. Inulinaceus*
(Group III (Minett) mastitis streptococci.)	
Usually ferments aesculin but not raffinose.	Usually ferments raffinose but not aesculin.
Slight turbidity in yeast dextrose broth.	Marked turbidity in yeast dextrose broth.
Final *p*H 4·7 to 4·9 in dextrose broth (*p*).	Final *p*H 4·3 (about).
No growth in bile salt (0·5 %) lactose broth (*q*).	Grows in bile salt lactose broth.

Str. Pyogenes (Human)	*Str. Pyogenes* (Bovine)
Ferments trehalose but not sorbitol.	Ferments sorbitol but not trehalose.
Does not hydrolyse starch (*r*).	Usually hydrolyses and ferments starch.
Final *p*H above 5·0.	Final *p*H below 5·0.
Fibrinolytic (human fibrin).	Not fibrinolytic (human fibrin).

Str. Diaceti-lactis [3]	*Str. Faecalis*
Marked aroma of diacetyl in milk.	No marked aroma of diacetyl.
Marked CO$_2$ production in milk.	No marked CO$_2$ production.
Rapid clotting (24 hr.) of milk at 22° C.	Usually requires 3 or more days to clot milk at 22° C.

Str. Faecalis	*Str. Inulinaceus*
Does not ferment inulin.	Ferments inulin.
Grows at 45° C.	No growth at 45° C.
Resists 30 min. at 60° C.	Killed by 30 min. at 60° C.

Str. Salivarius (" *Viridans* ")	*Str. Bovis*
Does not ferment starch and arabinose.	Ferments starch and arabinose.
Grows at 15° C.	Does not grow at 15° C.
Killed in 30 min. at 60° C.	Resists 30 min. at 60° C.

Str. Faecalis	*Str. Salivarius* (" *Viridans* ")
Resists 30 min. at 60° C.	Killed in 30 min. at 60° C.
Grows at 10° C.	No growth at 10° C.
Ferments mannitol.	Does not ferment mannitol.
Grows in 6·5 % NaCl broth.	No growth in 6·5 % NaCl broth.
Grows at *p*H 9·6.	No growth at *p*H 9·6.

Str. Pyogenes	*Str. Salivarius* (" *Viridans* ")
(*β*-haemolytic in blood agar)	(*a*-haemolytic or " greening " in blood agar)
Slight or no reduction in yeast dextrose litmus milk.	Marked reduction in yeast dextrose litmus milk.
No growth at 45° C.	Usually grows at 45° C.
Does not ferment raffinose.	Usually ferments raffinose.

STREPTOCOCCUS III

Str. Mesenteroides	*Str. Dextranicus*
Ferments arabinose, aesculin and (usually) mannitol and salicin.	Does not ferment these sugars.
Usually gives black colour with aesculin without addition of FeCl$_3$.	Black colour with aesculin when FeCl$_3$ is added.
Usually grows in bile salt (0·5 %) lactose broth.	No growth in bile salt lactose broth.
Grows at 5° to 10° C.	Does not grow below 10° C.

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[3] *Str. diaceti-lactis* may be regarded as a variant of *Str. faecalis*, producing large amounts of diacetyl, acetic acid, and CO$_2$. It may lose the power to do this on laboratory cultivation in milk. It may conveniently be classified, therefore, as a IIc-III intermediate.

Str. Dextranicus	*Str. Citrovorus*
Ferments mannose, sucrose, and maltose.	Does not ferment these sugars.
Gives black colour with aesculin when $FeCl_3$ is added.	No blackening with aesculin when $FeCl_3$ is added.
Good growth in suitable media (*e.g.* yeast litmus milk).	Growth never vigorous, best with beer-wort and malt extract (*t*).

Lactobacillus I

L. Casei [4]	*L. Plantarum* [4]
Usually long straight-sided rods in chains.	Usually short rounded rods in pairs.
Clots plain milk in about 5 days at 30° C.	Requires at least 14 days to clot plain milk.
No turbidity in whey.	Turbidity in whey.
Growth in milk not greatly stimulated by autolysed yeast.	Growth in milk greatly stimulated by autolysed yeast.
Final acidity in milk *c.* 1·5 % (*u*).	Final acidity in milk *c.* 1·0 %.

Lactobacillus II

L. Lactis [4]	*L. Helveticus* [4]
Moderate acidity in milk (1·0 to 1·6 %).	Very high acidity in milk (2·0 to 2·8 %).
Ferments sucrose, raffinose, and salicin.	Does not ferment these sugars.
Gives black colour with aesculin and $FeCl_3$.	No blackening with aesculin and $FeCl_3$.

L. Bulgaricus [5]	*L. Jughurt* [5]
High acidity in milk (*c.* 1·6 %).	Very high acidity in milk (2·0 to 2·7 %).

L. Acidophilus	*L. Lactis*
Usually does not ferment raffinose.	Ferments raffinose.
High acidity in milk (1·6 %).	Moderate acidity in milk (1·0 to 1·6 %).
No growth at 48° C.	Grows at 48° C.

L. Bulgaricus	*L. Acidophilus*
Does not ferment maltose, aesculin, and sucrose.	Ferments maltose, aesculin, and (usually) sucrose.
No growth in bile salt (0·5 %) lactose broth.	Grows in bile salt (0·5 %) lactose broth.
Grows at 48° C.	No growth at 48° C.

L. Acidophilus	*L. Bifidus*
No branching.	Branching in stab culture.
High final acidity in milk.	Low final acidity in milk.
Ferments aesculin but not xylose, arabinose and (usually) raffinose.	Ferments xylose, arabinose, and raffinose but not (usually) aesculin.
Good growth in milk.	Poor growth in milk.

Lactobacillus III

L. Pentoaceticus	*L. Fermenti*
No growth at 45° C.	Growth at 45° to 50° C.
Ferments arabinose.	Does not ferment arabinose.
No fermentation of raffinose, sucrose, and lactose.	Ferments these sugars.
Grows at 10° C.	Does not grow at 10° C.

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[4] Sometimes regarded as variants.

[5] Also regarded as variants. Many strains of *L. bulgaricus* received produced high acidities in milk.

L. Fermenti	*L. Buchneri*
Does not ferment arabinose. No growth at 15° C.	Ferments arabinose. Grows at 15° C.
L. Pastorianus	*L. Caucasicus*
Grows well in beer-wort and malt extract. Ferments raffinose, trehalose, and mannitol.	Slow growth in all media. Ferments only arabinose and hexoses.
L. Bifidus	*L. Pentoaceticus*
No growth at 20° C. or 45° C. Branching in stab culture. Usually ferments xylose, sucrose, raffinose, and salicin.	Grows at 20° C. and 45° C. No branching. Usually does not ferment these sugars.
L. Rudensis	*L. Pentoaceticus*
Forms a red-brown pigment in the presence of certain growth-factors.	Growth unpigmented.

Notes on Technique, Media, etc.

(*a*) It is recommended that microscopic examination of cultures be made always just before or at clotting, *i.e.* while the cells are in the logarithmic phase. This gives a standardised, physiological time—an absolute time, *e.g.* 24 hr., is obviously unsound in view of the great differences in growth rates. Litmus milk and yeast dextrose litmus milk are recommended for this purpose.

(*b*) Medium : 1 per cent. dextrose, 0·5 per cent. peptone, 0·3 per cent. lemco adjusted to pH 6·8. Yeast extract is purposely omitted in order to utilise the different growth requirements of the two organisms.

(*c*) The results of the sugar fermentation tests depend enormously on the nitrogen source used. Probably the best all-round basal nitrogen source is casein double-digest broth (equivalent to 1 per cent. casein) plus 0·5 per cent. yeastrel. The N.I.R.D. autolysate contains about 1 per cent. nitrogen (all non-protein) and yeastrel about 5 per cent., so that five times the amount of prepared autolysate should be used. Peptones vary considerably in their growth-promoting properties for lactic acid bacteria, but this variability is almost removed if yeast is added. In practice, therefore, the most convenient base for sugar fermentation work is 1 per cent. peptone + 0·5 per cent. yeastrel or similar yeast autolysate. Group III types will not form gas readily in this medium, however, and unfiltered malt extract is recommended for detecting this.

(*d*) It is most important in temperature range work to warm or cool the media to the required temperature before inoculation. Failure to do this will result in cases of " slight growth " at temperatures at which the cultures will not properly grow.

(*e*) *Str. cremoris*, *Str. thermophilus*, *L. bulgaricus*, and *L. jughurt* are distinctive in growing well in plain milk and poorly in all other media.

(*f*) NaCl. It is essential to carry out these and similar (pH and sodium lactate) tests in broth media. Conflicting results are obtained if solid media are used. Sodium lactate broth : 2 per cent. (or as required) sodium lactate, 1 per cent. dextrose, 0·5 per cent. peptone, 0·3 per cent. yeastrel, pH 6·8.

(*g*) pH. Broth media must be used and the tubes sealed immediately after inoculation. Holding in airtight containers with soda lime is not good enough. pH values should be checked before and at the end of the incubation period (7 days).

(*h*) It is essential to carry out this test carefully. In this, as in all other biochemical tests, positive and negative controls should be employed, *i.e.* with organisms known to be positive and negative for the test.

(*j*) *Str. agalactiae* is the only lactic acid bacterium giving this reaction, which is therefore a distinctive one. *L. rudensis* (a pigment-forming variant of *L. pentoaceticus*) is the only other lactic organism to form pigment consistently, although other types do so occasionally.

(*k*) A convenient routine method is to inoculate 5 ml. of milk or sugar broth at *p*H 6·6 to 6·8 and to immerse the tube up to the top in the water bath at the required temperature. A thermometer previously standardised is held in a control tube, and the time taken from when this reaches the temperature of the bath.

(*l*) Although brom-cresol-purple is the best *p*H indicator for detecting acidity in milk, litmus is invaluable in revealing both acidity and reduction. The *Eo* of litmus is ideally suitable for differentiating the strongly and weakly reducing types of lactic acid bacteria.

(*m*) For the technique of the metabolic test *see* Davis (1939), *Zbl. Bakt.*, II, **101**, 97. The Voges-Proskauer test is made by adding a knife-point of creatine and 1 ml. of 40 per cent. NaOH to 1 ml. of culture and observing after 1 to 30 min. The most sensitive methods of performing the test should be avoided as otherwise the test loses its value. *Str. faecalis* and its variants are the only lactic organisms producing diacetyl under these conditions.

(*n*) The faecal sub-group (IIc) are clearly differentiated by the above metabolic reaction, ability to grow on non-sugar media, heat resistance, growth at high and low temperatures, and ability to survive for over a year on agar slope cultures at room temperature. Most lactic acid bacteria will give slight growth with peptone, etc., only because all proteins contain traces of sugar.

(*o*) The toxicity of crystal violet and sodium azide, as of all other inhibitors, depends on the concentration of nutrients and especially of protective substances, such as milk. The following standardised medium is therefore suggested: 1 per cent. dextrose, 0·5 per cent. peptone, 0·3 per cent. yeastrel, 1 per cent. separated milk, *p*H 6·8.

(*p*) We have not obtained such clear-cut results with final *p*H tests as those reported in the literature. It is suggested, therefore, that only well-marked differences, as in the present case, should be considered as of diagnostic value.

(*q*) The ordinary MacConkey broth for coli tests may be used.

(*r*) Employ heavy streaking on plates of the following medium: 1 per cent. starch, 0·5 per cent. peptone, 0·3 per cent. yeastrel, 1·5 per cent. agar, *p*H 6·8.

(*s*) Medium: 1 per cent. peptone, 0·3 per cent. yeastrel, 0·5 per cent. NaCl (most important). *p*H 7·0. Add 5 per cent. defibrinated cow blood at 48° C. Blood is easily contaminated, so always pour control plates. Incubate 24 hr. at 37° C. and examine colonies with a ⅔-in. objective. Only colonies surrounded by a sharply defined zone clear, or practically clear, of corpuscles, should be considered truly haemolytic. Refrigerate for 24 hr. and re-examine for types.

(*t*) *Str. citrovorus*, *L. caucasicus*, and *L. pastorianus* are nutritionally similar and grow very poorly unless beer-wort, etc., is included in the medium. Beer-wort litmus milk (litmus milk containing 5 per cent. beer-wort) is a useful medium for these types.

(*u*) Values given in this paper include that for sterilised separated milk (about 0·16 per cent. lactic acid).

Refs.: Bergey; Hammer; Rogers; Wilson and Miles; Ernst (1942), *The Epidemiological Significance of Grouping and Typing the Haemolytic Streptococci*, London; Orla-Jensen (1919 and 1943), *The Lactic Acid Bacteria*, Copenhagen; Frost and Engelbrecht (1940), *The Streptococci*, Madison; Tittsler *et al.* (1952), *BR*, **16**, 227; Sherman (1939), *Bact. Reviews*, **1**, 1 (streptococci); Hirsch (1952), *JDR*, **19**, 288 and 290 (streptococci); Briggs and Newland (1952, *JDR*, **19**, 160 (*Str. cremoris*); Briggs (1952), *JDR*, **19**, 167 (*Str. diacetilactis*); Pederson (1949), *BR*, **13**, 225 (*Pediococcus*); Swartling (1951), *JDR*, **18**, 256 (citric acid fermenting cocci); Morris and Edwards (1949), *JDR*, **16**, 161 (*Str. lactis* morphology); Nichols and Hoyle (1949), *JDR*, **16**, 167 (phage typing of streptococci); Abd-El-Malek and Gibson (1948), *JDR*, **155**, 233 (streptococci in milk); Costilow and Speck (1951), *JDS*, **34**, 1104 (inhibition by fatty acids); Krishnaswamy and Babel (1951), *JDS*, **34**, 374 (diacetyl); Seelemann and Carstens (1951), *M*, **6**, 231 (serology streptococci); Möller (1950), *M*, **5**, 313, 359 (growth factors); Demeter (1949), *M*, **4**, 97 (effect of Mn); Shattock (1949), *JGM*, **3**, 80 (*Str. bovis*); Sharpe (1951), Ph.D. thesis, Reading (streptococci); Hunter (1946), *JDR*, **14**, 283 (medium for streptococci); Davis (1944), *DI*, **9**, 22 and 181 (synonyms); Thiel (1940), *JDR*, **11**, 136 (fermentation of heterofermentive lactobacilli); Davis and Thiel (1939), *JDR*, **10**, 455 (effect of *p*H); Hunter (1939), *JDR*, **10**, 464 (variation in *Str. cremoris*); Davis (1939), *JDR*, **10**, 186 and 196 (nutritional aspects); Braz and Allen (1939), *JDR*, **10**, 20 (metabolism); Davis (1939), *JDR*, **9**, 85 (Eh and volatile acid production); Minett (1935), *JH*, **35**, 504 (mastitis streptococci); Briggs and Briggs (1954), DSA, **16**, 251 (lactobacilli).

LACTIC ACID FERMENTATION. The changing of sugars, especially lactose in milk, to lactic acid by the enzymes of bacteria and other cells. Broadly two classes of fermentation are known : (i) the almost pure fermentation

sugar → lactic acid + carbon dioxide, etc.
98 to 99 per cent. 1 to 2 per cent.

(ii) the mixed fermentation

sugar → lactic acid + acetic acid + carbon dioxide
c. 50 per cent. *c.* 50 per cent.

The first is characteristic of muscle and Groups I and II lactic acid bacteria (p. 378) and the second of Group III lactic acid bacteria, coliforms, *Serratia*, and many other types. *See* Classification ; Coliforms ; Lactic acid bacteria.

Refs. : Orla-Jensen ; Prescott and Dunn ; Stephenson ; Bact. reviews (*JDR*) ; Hullin and Noble (1953), *BJ*, **55**, 289 (determination).

LACTIC CHEESE. *See* Cheese, p. 195.

LACTOBACILLUS. *See* Lactic acid bacteria.

LACTOCHROME. The original name for the water-soluble, yellow-green fluorescent pigment in milk and whey. It was subsequently called lactoflavin and is now generally called riboflavin. It is the chief constituent of the vitamin B_2 complex (p. 1059). *See* Vitamins.

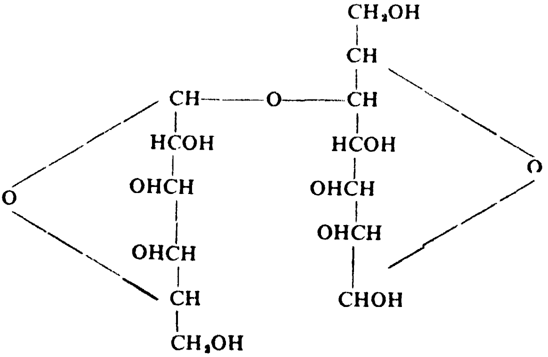
LACTOGLOBULIN. *See* Globulin.

LACTOMETER. A special type of hydrometer for measuring the sp. gr. of milk and covering the range 1·025 to 1·035. The density is usually expressed as degrees of gravity, *e.g.* 1·032 is called 32 degrees of gravity. The form commonly in use in dairy laboratories is the Richmond type ; some laboratories use the B.S.I. type and it is most important to distinguish these, as different techniques and formulae are used. (*See* Total Solids.) Lactometers can be conveniently used as a rough sorting test for watered milk in churns on the receiving platform. It is also important to calibrate lactometers to read either at the top of the meniscus or at liquid level, preferably the former. *See* Density ; Richmond's formula ; Solids-not-fat ; Total solids.

Ref. : *Milk Testing* ; Richmond ; Humphriss (1953), *DI*, **18**, 498 (improved apparatus).

LACTOMUCIN. A mucoprotein isolated from the protein membrane which surrounds the fat globules in milk. *See* Membrane.

LACTOSE. The sugar of milk, a disaccharide which is characterised by being fermented or broken down only by certain micro-organisms and tissues. It occurs to the extent of about 4·8 per cent. in cow's milk and about 6·4 per cent. in human milk, but is depressed in cases of udder disease (*see* Abnormal milk ; Mastitis). Lactose is not found elsewhere. On hydrolysis it is split into *d*-glucose and *d*-galactose



glucose γ-galactoside

Lactose occurs in three modifications: (i) α-monohydrate, crystallising from solutions below 93° C. and forming the ordinary, stable *milk sugar* of commerce. This form exhibits muta-rotation (finally + 55·5°); (ii) β-lactose, stable at above 93° C. (anhydrous); (iii) α-lactose, formed *in vacuo* from (i).

Properties. α-lactose exists as rhombic prisms sp. gr. 1·54; solubility in water 16 per cent. (cold), 40 per cent. (hot); composition: *C* 40·0, *H* 6·11, *O* 48·89 per cent. Reduces Fehling's solution and ammoniacal silver. On heating forms acids and other decomposition products with browning. *See* Browning; Sterilised milk.

Estimation. Lactose is most conveniently determined polarimetrically. It can also be estimated by gravimetric and volumetric copper methods, and by iodine.

Refs.: Davies; Richmond; Rogers; Francis and Smith (1952), *JDR*, **19**, 83; Babad and Grunpeter (1951), *JDR*, **18**, 147; Larsen and Gould (1951), *JDS*, **34**, 16 (heat destruction); Choi *et al.* (1951), *JDS*, **34**, 845, 850 (crystallisation in products); Potter (1950), *JDS*, **33**, 803 (hydrolysis); Perry and Doan (1950), *JDS*, **33**, 176 (det. lactose and sucrose); McDowell (1941), *JDR*, **12**, 131 (estimation in milk).

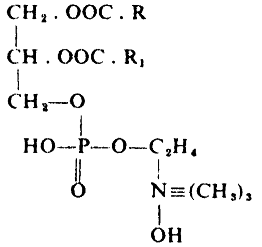
LANCASHIRE. *See* Cheese, p. 195.

LAURIC ACID. *See* Fatty acids.

LEAD. Lead is not used for milk plant or containers as it dissolves slowly in souring milk. It is still sometimes used for storing whey for pig food.

LEBEN. An Egyptian fermented milk of the *L. bulgaricus* type. It is said sometimes to contain a lactose-fermenting yeast which induces an alcoholic fermentation.

LECITHIN. Lecithins are phospholipoids having the following structure:



$$\begin{array}{lll} CH_2.OOC.R & & \\ | & & \\ CH.OOC.R_1 & & \\ | & & \\ CH_2{-}O & & \\ \quad\;\; | & & \\ HO{-}P{-}O{-}C_2H_4 & & \\ \quad\;\; \| \qquad\quad | & & \\ \quad\;\; O \qquad\; N{\equiv}(CH_3)_3 & & \\ \qquad\qquad\quad | & & \\ \qquad\qquad\; OH & & \end{array}$$

The molecule contains glycerol, usually one saturated acid such as palmitic or stearic, one unsaturated acid such as oleic, phosphoric acid, and choline. Lecithin is extremely active chemically and readily undergoes auto-oxidation. It is present to the extent of about 0·05 per cent. in milk and is easily destroyed by heat. It gives rise to a fishy taint in butter, etc., through liberation of trimethylamine. *See* Auto-oxidation; Fishiness.

Refs.: Davies; Rogers.

LEFFMAN-BEAM METHOD FOR FAT DETERMINATION. This method is reliable but has now been superseded by the Gerber method (p. 489) in this country. It may be regarded as intermediate to the Babcock and Gerber methods since it utilises open flasks with a calibrated neck, and sulphuric acid together with a mixture of amyl alcohol and hydrochloric acid to assist in the separation of the fat (Leffman and Beam, 1892, *A*, **17**, 83).

LEGAL ASPECTS. The adulteration of food has been practised probably from the times of antiquity, but it was not until 1860 that any general Act was passed dealing with food adulteration. There had been, previous to this, special statutes dealing with individual foods, some indeed dating back to the sixteenth century, but these had as their main object the protection of the revenue.

In 1850 the medical journal *The Lancet* appointed a Sanitary Commission, and continuously published articles derived from its work. In 1855 many of these publications were reissued in book form under the title of *Food and its Adulterations*. As a result, the Government was stirred to action and set up a Parliamentary Committee to study and report on food adulteration. The outcome was the Adulteration Act of 1860. A further Act was passed in 1872 but without repeal of the former.

These Acts made it an offence to adulterate any food or to sell any food containing any harmful additions, but their effective operation was seriously hampered by the absence of any standards. Although the 1860 Act arranged for the appointment of analysts, it afforded them no assistance in indicating acceptable standards. The analyst, therefore, became the sole arbiter in pronouncing on a sample's genuineness, and his inexperience in these early days increased the difficulties.

The legal position was improved, however, by the passing of the Food and Drugs Act, 1875, which repealed the earlier Acts, and provided for the appointment of Public Analysts by the authorised authorities, such appointments being made compulsory under an amending Act in 1879. All the Acts with the exception of a few sections—were repealed by the Food and Drugs (Adulteration) Act of 1928.

All legislation regarding adulteration in Great Britain is mainly in broad terms, and very few articles of food have any definition of genuineness. Milk, and certain milk products, are among these few. Milk, by reason of its naturally widely varying composition, is impossible of absolute definition in analytical terms, and considerable concern arose in the early days of milk legislation regarding the interpretation of analyses. The wide range in the composition of milk as yielded by the individual results from many causes, *e.g.* breed, period of lactation, the season, etc. (*see* Composition, factors affecting). This presents an unsurmountable difficulty in the fixing of absolute standards of genuineness, and no precise legal definition of milk exists. Various definitions have been put forward at different times, but they only generalise, regarding " genuineness " as the composition of milk as it comes from the cow. Sir George Brown, the veterinary adviser to the Board of Agriculture, giving evidence before the Interdepartmental Committee in 1901 described genuine milk as " the fluid drawn from a perfectly healthy udder of a perfectly healthy cow living under the most favourable sanitary conditions ". A large proportion of the milk supply to-day would fail to come within this definition.

The law has always been more concerned with the compositional quality of milk, its principal object being, apparently, to protect the public from fraud, but there is now a definite movement towards sanitary control. The first real legislation in this respect is the Milk and Dairies Order, 1926.

The passing of the Sale of Food and Drugs Act, 1875, permitted the appointment of Public Analysts, who were called upon to pronounce on the genuineness of the samples they examined. The absence of milk standards, it was felt, left too much to the analyst's judgment, and the newly formed Society of Public Analysts decided to adopt limits below which it thought genuine milk should not fall, as a guide to its members. These limits were, not less than 9 per cent. by weight of solids-not-fat, and not less than 2·5 per cent. fat. This low fat figure may be explained by the fact that it was based on Wanklyn's method, which did not give complete extraction of the fat. This method was later abandoned in favour of the more satisfactory paper-coil method of Adams, the limits then being altered to 8·50 per cent. solids-not-fat and 3 per cent. fat, at which figures they remain to-day.

It will be observed that these limits are only presumptive standards of genuineness, and they have given rise to an interesting point in law. It is axiomatic in English law that a man must be held to be innocent until he is proved to be guilty, the onus of such proof resting on the prosecution. In milk adulteration cases, however, this axiom is entirely reversed, a dairyman selling milk of a quality below the presumptive standards is held to be guilty unless and until he himself can prove his innocence. In the early days this was by no means easy, and it is probable that many milk-vendors were unjustly convicted. Indeed, the probability was sufficiently strong to induce the Government to set up a Select Committee to enquire into and report upon the working of the Act, which had already been amended in 1879. (The Sale of Food and Drugs (Amendment) Act.) This Select Committee reported in 1894, and embodied this conclusion:

> " As the law stands at present, all milk, *whatever its composition*, which is the produce of a cow, and to which nothing has been added, and from which nothing has been abstracted, must be regarded as pure, and its sale is no offence under the Adulteration Acts."

The Committee, however, would not accept the responsibility of formulating standards. The operation of the Act still continued to cause dissatisfaction, largely on account of many enforcement authorities and magistrates regarding the presumptive limits of genuineness as absolute standards. Indeed, Parliament was sufficiently disturbed by the situation to empower the Board of Agriculture, by the passing of an amending Act in 1889, to make regulations, after such enquiry as it deemed necessary, for determining what deficiency in the normal constituents of genuine milk should raise a presumption, until the contrary was proved, that the milk was not genuine. Under the power provided the Board appointed a Committee of Enquiry, under the chairmanship of Lord Wenlock.

This Inter-departmental Committee—more familiary known as the Wenlock Committee—thoroughly explored the whole matter and issued its report in January 1901. One member, of the eight members, however, declined to sign the Report, embodying his reasons and his recommendations in a separate Minority Report.

The member in question was Sir (then Mr.) George Barham, the founder of the Express Dairy Company, who possessed the accumulated knowledge of an unique experience of milk production, and it was, in fact, his Minority Report which was accepted by the Board of Agriculture. It remains to-day as the basis of the law on the sale of milk.

There is one modification in the presumptive standards recommended by Mr. Barham in the Amending Act which followed his Report. He had suggested that the lower limit of fat in genuine milk should be of seasonal variation. Whereas the Majority Report called for a uniform limit of 3·25 per cent., Mr Barham wanted limits of 3 per cent. from July to February inclusive, and 2·75 per cent. from March to June inclusive. It must be remembered that at this time there was no bulking of milk as we have it to-day, and milk as retailed was generally individual herd milk, some of the herds being very small. The seasonal decline in fat could, therefore, easily happen to a point which might be below 3 per cent. in many cases, and certainly below the figure of 3·25 per cent. recommended by the Majority Report. The Amended Act (*i.e.* Sale of Milk Regulations, 1901), however, imposed limits of 3 per cent. all the year round, apparently in the belief that a less rigid figure might be a temptation to adulterate. This figure, and the solids-not-fat limit of 8·50 per cent. remain to this day, but they are only presumed limits of genuineness and not absolute standards.

Excepting for a slight modification of this Act in 1912, no further milk legislation was introduced until 1923. This was the Milk (Special Designations) Order made by the Minister of Agriculture under the Milk and Dairies (Amendment) Act of 1922. For some years before this time the need for sanitary improvement of the milk supply had become evident and, indeed, just before the first World War Mr. John Burns, then President of the Local Government Board, was framing a bill with this object. This was the Milk and Dairies (Consolidation) Act, 1915, which was scheduled to come into operation not later than one year after the end of the war. This did not happen, however, a postponing Act being passed in the same year, and it was not until 1922 that any further legislation was considered. In the interval, *i.e.* 1919, the Local Government Board ceased to exist and its powers were transferred to a new Ministry—Health, and it was the Minister of Health, therefore, who introduced the Milk and Dairies (Amendment) Act, 1922, which postponed the operation of the 1915 Consolidated Act until 1925, and made further provisions regarding the sale of milk.

This Act operates to-day, by its substantial incorporation in the Sale of Food and Drugs Act, 1938, forming Sec. 2 of that Act. The Milk and Dairies (Amendment) Act, 1922 was the first legislation in this country to have regard to bacteriological standards for milk, for in 1923, under the power conferred upon him by Sec. 3 of the Act, the Minister of Health issued, under Statutory Rules and Orders, No. 601, the Milk (Special Designations) Order, 1923, to become operative on the first day of July of that year. This Order particularly merits our attention as it made the first absolute standards for milk. It did not concern itself with the composition of milk, which was and still is, the business of the Sale of Food and Drugs Act, but it did define bacteriological standards in respect of certain designated milks. It aimed to effect some sanitary improvement of the milk supply without coercion, but, of course, being non-compulsory, it was operated by the issue of licences which could be revoked in the case of non-compliance with their terms. It was hoped that the inducement of a higher price for the milk would prompt farmers to undertake the production of these superior milks, and so encourage the raising of sanitary levels. The Order made the following designations : (1) Certified. (2) Grade A (Tuberculin Tested). (3) Grade A. (4) Grade A (Pasteurised). (5) Pasteurised.

The first two grades were required to be the produce of tuberculin-tested cows. To gain a licence to sell this milk, the producer had to show a certificate of a registered veterinary surgeon showing the results of an examination of the herd carried out not more than 3 months before the application for the licence, and a certificate of a prescribed tuberculin test of the herd carried out within a similar period.

The tuberculin test was required to be continuously performed at 6 monthly intervals. There were too, naturally, conditions imposed regarding the arrangements for the production, storage, treatment and distribution of the milk. Further, it was forbidden to subject this milk to any form of heat-treatment. The bacteriological standards which were imposed were two, *viz.* : that a sample taken at any time before delivery to the consumer should contain not more than a prescribed number of bacteria per c.c., and no coliform bacillus outside certain limits. In the case of certified milk the number of bacteria per c.c. was limited to 30,000 and *B. coli* to be absent from 1/10 c.c. This milk had to be actually bottled on the farm at the time of production, the bottle being closed with a disc and covered with a suitable outer cap overlapping the lip of the bottle and so fastened as to form a complete seal. The cap had to bear the name and address of the producer, or the dairy where the milk was produced, the day of production, and the words " Certified Milk ".

Grade A (Tuberculin Tested) was essentially the same as " Certified ", but it was permissible for it to be sent off the farm in bulk, to be bottled by a distributing dairy which was appropriately licensed. The object of this would appear to have been not to discourage the production of Tuberculin Tested milk where the farmer might have difficulty in handling a bottled supply. It was evidently appreciated that the extended handling would have an effect of an increased bacterial content, and the limit per c.c. was, therefore, fixed at 200,000, *B. coli* to be absent from 1/100 c.c. When bottled, this milk had to be capped similarly to Certified, to bear the name and address of the bottler, the date of the bottling, and the words " Grade A (Tuberculin Tested) Milk ".

Grade A milk, the third in order of values, is one which has been the subject of very adverse comments. This milk was not the product of tuberculin-tested cows. So far as the cattle were concerned, all that was required to obtain the licence was a certificate from the veterinary surgeon that a physical examination had proved satisfactory. It will be appreciated that tuberculosis, abortion, subclinical mastitis, and other conditions may not necessarily be evident in a physical examination and it was largely thought that it was wrong to attach a designation like " Grade A " to such milk, especially as the average person, not unnaturally, assigns the meaning " the best " to such a term. However, the Minister apparently recognised its weakness, as this milk was permitted to be pasteurised, when it was designated " Grade A (Pasteurised) ". In this latter state the bacterial standards were the same as for Certified milk, *i.e.* not more than 30,000 bacteria per c.c., and the coliform bacillus to be absent in 1/10 c.c.

Lastly, there was " Pasteurised Milk ", which the Order defined as " any milk that after pasteurisation contains not more than 100,000 bacteria per c.c. ". Pasteurisation was to be performed on a plant duly licensed by the Minister and meant holding the milk for not less than 30 min. at a temperature of not less than 145° F., or more than 150° F., and immediately cooling to a temperature not exceeding 55° F.

The Milk (Special Designations) Order, 1923, remained unaltered until 1936. In April of that year certain changes were made, arising, it is supposed, from the experiences gained by the operation of the original Order, and the increase in knowledge of milk bacteriology during that period.

By the 1923 Order, Tuberculin Tested milk was not permitted to be heat-treated, but it had become obvious that even a well produced milk from a tuberculin-tested herd was not necessarily free from risk to the consumer. It had been found, for instance, that *Brucella abortus* was by no means uncommon in Tuberculin Tested milk. Under this Order, therefore, Tuberculin Tested milk may be pasteurised, provided the fact is disclosed, and the heating performed according to the statutory requirements. The consumer has the option, however, of taking this milk raw or pasteurised.

The 1936 Order rescinded the plate count standards for raw milks and substituted the methylene blue test, but the coliform tests were maintained. Naturally, new standards had to be made for Tuberculin Tested (Pasteurised), which were a plate count maximum of 30,000 and coli to be absent in 1/100 ml. The 1936 Order also revoked the designation " Grade A ", and introduced a new one in " Accredited " milk. The difference is one of name only, the production conditions remaining practically identical. No special provision is made in respect of handling this milk, for which the producer is paid an extra price, other than the requirement that all vessels used in conveying it shall be labelled " Accredited Milk ". The designations under this Order are, therefore: (1) Tuberculin Tested (Certified) Milk. (2) Tuberculin Tested Milk. (3) Tuberculin Tested (Pasteurised) Milk. (4) Accredited Milk. (5) Pasteurised Milk.

This was the position up to 1946 when a further alteration of the Order came into effect on March 1st. For many years the plate count has been regarded as unsatisfactory, both on account of its large normal error and the fact that it is intended to show whether milk has been properly pasteurised.

It need not be explained that it is only a matter of time and temperature before perfectly pasteurised milk of the highest hygienic quality will fail to conform to the bacterial standard laid down in the Order. Also, generally speaking, the Local Authorities, who administer the Order on behalf of the Ministry of Health, appear to regard the plate count as an absolute measure of the intrinsic quality of the milk, instead of an index as was originally intended.

It is true, of course, that in 1923 there was no test available which could measure the efficiency of pasteurisation and the plate count was necessarily adopted as being the only test which could be usefully employed to give some indication of the situation. The view was, that if milk were properly pasteurised on a clean plant, and carefully handled during distribution, the count should not exceed the number laid down. The Ministry, however, did realise its weaknesses and Local Authorities were circulated to the effect that occasional samples might be unsatisfactory and that no action should be taken unless three successive samples failed to conform. In such case it was reckoned to be a reasonable assumption that something was at fault.

With the advent of the phosphatase test, it was felt that the plate count for pasteurised milk could not long survive and it was discontinued in favour of the new test from March, 1946. At the same time the methylene blue reduction test was also applied to pasteurised milk, the minimum time of reduction being 30 min.

This is a broad outline of the laws relating to the sale of milk so far as its qualities are concerned, but there are, of course, other legal requirements which are concerned with the production and handling of milk.

In 1938 the whole of the existing legislation was incorporated in a single Act, *viz.* the Food and Drugs Act, 1938. It is really a consolidation Act, since it made no material alteration in the law, but confined itself to some redrafting, some simplification of procedure, and a few minor alterations. It includes about 250 provisions found in some 36 Acts, some of them very old, and contains the whole of the law on Public Health in 103 sections, a noteworthy achievement in legislation.

Administration of the Act rests with two classes of authorities, *i.e.* the " Local Authority " and the " Food and Drugs Authority ". They are, for London, the Common Council of the City and the Metropolitan Borough Councils. Outside London, they are the Borough Councils and the County Council except any non-county borough or urban district with a population of 40,000 or upwards. The Minister of Health has the power to confer this authority upon any non-county borough or urban district with a population of 20,000 to 40,000.

Penalties for breaches of the law have been much simplified in the 1938 Act. Previously, penalties differed widely in the various Acts, but the principle has now been adopted throughout the Act of a uniform general provision of a maximum penalty for the first offence of £20 and £100, or 3 months' imprisonment, or both, for the second.

As to Regulations, penalties under the Food Regulations and the Milk and Dairies Regulations, by Sec. 92, may be prescribed by the Regulations themselves, but they are limited to the maximum penalties set out in the Act, by Sec. 92. The view was taken that such a wide variety of offences could be committed under these Regulations that no single penalty clause could be appropriate in all cases.

Certain statutory defences are available to defendants under the Sale of Food and Drugs Act. An important one, Sec. 84, is the pleading of a warranty. In such cases the defendant is required to prove : (1) That he purchased the article as being of such a nature, substance, and quality, and with a written warranty to that effect. (2) That he had no reason to believe that at the time of the commission of the offence that it was otherwise. (3) That it was then in the same state as when he purchased it.

The Act further requires that if a warranty defence is pleaded the defendant must (1) Send to the prosecutor within 7 days of the service of the summons a copy of the warranty with a notice of his intention to rely on it, and stating the name and address of the person from whom he received it, and send on a like notice to that person. (2) That he shall give notice within 60 hours of the sample being procured, to the Sampling Authority stating the name and address of the seller or consignor of the milk, and requesting that another sample be taken as soon as practicable at the same time and place of delivery to himself, or in the course of transit or delivery to himself.

This requirement is not valid if the sample was taken from a mixture of milk obtained from more than one person, and practically limits the matter to the supply of milk from cows in a dairy. In this case, we have the " appeal to the cow ", a sample being taken from a corresponding milking.

Another defence is available under Sec. 83. Here, if the defendant can prove that the act or default of some other person brought about the contravention of the provisions in question, he can lay such information and give not less than 3 days' notice requiring this person to be brought before the court in the proceedings. If, after the contravention has been proved, the original defendant proves it was due to the act or default of the other person, that other person may be convicted of the offence, and if he further proves that he has used all due diligence to secure that the provisions in question had been complied with, he would be acquitted. If, however, he fails to prove due diligence, both defendants may be convicted.

Under this Section the Authority, being satisfied that the offence was due to the act of someone other than the purveyor from whom the sample was procured, and that the purveyor could establish this defence, can cause proceedings to be taken against such other persons without first causing proceedings to be taken against the first person.

As we have shown, the first principle of the law relating to milk is in respect of adulteration so far as it may be presumed by chemical analysis, but there are many legal requirements in connection with the machinery of selling, offences against which may also be the subject of proceedings in a magistrates' court. The principal Regulations are contained in the Milk and Dairies Order, 1926 (S.R. and O. 82), which revoked the old Dairies, Cowsheds, and Milk-shops Orders of 1885, 1886, and 1899. The principal provisions of this Order are : (1) The registration of all persons carrying on the trade of cowkeeper or dairyman, and of all farms and other premises by the sanitary authority for the district. (2) The health and inspection of cattle. (3) The cleanliness of dairies, etc., and the protection of milk against infection and contamination. (4) Conveyance and distribution of milk.

The Milk and Dairies Order, 1926, is extremely comprehensive and if its provisions were properly enforced, would go far to raise the general sanitary quality of the milk supply to a more satisfactory level. Unfortunately, for many reasons, the Order is practically unenforced in very many areas, especially in rural areas where, in fact, the need is greatest.

The Government, indeed, has recognised the weakness of this situation, and in a Memorandum on Milk Policy issued in 1942 (Com. Paper 6362) and a White Paper in 1943 indicated its intention of making substantial alterations in the present administrative machinery. The Food and Drugs (Milk and Dairies) Act 1944 operative from 1st October, 1949 (and now consolidated in the Food and Drugs (Milk Dairies and Artificial Cream) Act 1950) brought about some far-reaching changes.

In accordance with Section 1 of the Act, the Minister of Agriculture and Fisheries replaces the local authority as the authority responsible for registering dairy farmers and dairy farms, the local authority being responsible only for the registration of distributors and their premises, other than dairy farms. Producers and retailer-producers who distribute milk from their farms, and not from any shop or other premises off the farm, are solely under the jurisdiction of the Minister of Agriculture and Fisheries, excepting in matters relating to infected milk and the spread of disease thereby, which continue to be dealt with by local medical officers of health. Thus the industry is now divided into two parts, production and distribution, administered respectively by the Ministry of Agriculture and the local authorities. Thus, whilst the old Regulations referred to both producer and distributor collectively as " dairyman ", they are now defined as " dairy farmer " and " distributor ".

Acting jointly under powers conferred on them, the Minister of Health, the Minister of Agriculture and Fisheries and the Minister of Food made the Regulations entitled the Milk and Dairies Regulations, 1949, which apply to England and Wales, but not to Scotland. These Regulations replace the Regulations of 1926-43, and are of a much more comprehensive character. An important change is that of the administrative authority already referred to, and the Ministry of Agriculture has power to refuse to register dairy farmers and farms, or to cancel existing registrations.

For the benefit of persons whose registration may be refused or cancelled, Appeal Tribunals are set up, consisting of a chairman appointed by the Ministry and two members representative of the producers' and consumers' interests respectively, to which an aggrieved person's case may be referred by the Minister for hearing and guidance. A Central Committee and County Advisory Committees are also constituted, which keep under review the operation and administration of the Regulations. The County Committees may make recommendations to the Central Committee as they deem desirable, which may be referred to the Minister. County Committees consist of representatives of the County Council, the Local Authorities, the County Agricultural Executive Committee, producers, distributors and veterinary surgeons, under a chairman appointed by the Minister.

Neither the Central nor the County Advisory Committees had been formed by 1953. The Food and Drugs Amendment Bill presented to the House of Lords in November, 1953, proposed the repeal of the Regulations providing for the setting up of these Committees.

The Milk and Dairies Regulations, 1949, also include new provisions for the inspection of cattle on dairy farms by veterinary surgeons of the Ministry of Agriculture and Fisheries.

Minor changes in the Regulations relate to buildings, the cleaning of utensils, the distribution of milk and its protection from contamination and infection. Provision is made for modern practice in the building of dairies, in milking and the use of mechanical refrigeration. The use of approved preservative agents, *i.e.* sodium hypochlorite solutions—previously only permitted by a war-time Provisional Order—is regularised. Licences are for yearly periods ending 31 December.

The Milk and Dairies Regulations, 1949, really embrace all the fundamental aspects of dairying, and their provisions should be known to everyone engaged in the industry. In fact, by Part I, paragraph 4, a statutory onus is placed on every dairy farmer and distributor to take all practicable steps to make the provisions of these Regulations known to every person in or about his registered premises so far as such provisions impose any duties or restrictions on such persons, or relate to any processes.

Although the previous Milk and Dairies Regulations also contained this clause, it is regrettable to remark that a very large section of the industry failed to observe it, and the writer strongly recommends that every responsible person should possess a copy and make himself and those in his charge completely familiar with at least those provisions which refer to his and their particular duties. The Regulations have been often described as the "dairyman's bible", and while their cost is trifling, their value is incalculable to everyone who desires to conduct his business with the knowledge it requires and deserves.

Further regulations issued under the Milk (Special Designations) Act, 1949, deal with the designated milks. One set of these Regulations refers to raw milks and is entitled : Milk (Special Designations) (Raw Milk) Regulations, 1949, and the other is the Milk (Special Designations) (Pasteurised and Sterilised Milk) Regulations, 1949, and they replace the Milk (Special Designations) Regulations, 1936-48.

The raw milks regulated by the first are Tuberculin-tested and Accredited, but the production of "Accredited" milk is restricted to five years from 1 October 1949. It is hoped that by that time "Accredited" producers will have up-graded their herds to Tuberculin-tested standard. The designation "Certified" no longer operates, and Tuberculin-tested milk bottled on the farm is now described as "Tuberculin-tested Farm-bottled". The only statutory test for designated raw milk is the methylene blue test which requires that the milk shall not decolorise it in less than four and a half hours in the summer (1 May to 31 October) and five and a half hours in the winter (November to April inclusive), the coliform test—previously optional—now being omitted.

With regard to Tuberculin-tested milk, it is important to note that after three years from the operation of the Regulations, the designation may only be applied to milk produced from a herd which is on the Ministry of Agriculture's register of " Attested herds ". Licences granted to producers with Attested herds will remain valid for five years, and are renewable for similar periods, but licences for Tuberculin-tested milk from non-attested herds are granted only for three years from 1 October 1949, or such shorter period to expire on 30 September 1954, and are not renewable.

The Pasteurised and Sterilised Milks Regulations are made jointly under Sections 21 and 22 of the Food and Drugs Act, 1938, as amended by the Food and Drugs (Milk and Dairies) Act, 1944, by the Minister of Health and the Minister of Food, and they create a new designation, " Sterilised ".

The Regulations require that " Sterilised " milk shall be clarified or filtered, homogenised and heated at such a temperature—not less than boiling-point—for such a time that the milk satisfies a prescribed test. This treatment needs no departure from orthodox practice. The prescribed test is the " turbidity " test, and is performed by adding 4 g. of ammonium sulphate to 20 ml. of milk. When precipitation is complete, or after five minutes, it is passed through a No. 12 filter paper, and 5 ml. of the clear filtrate collected in a test tube. The tube is placed in a beaker of boiling water for five minutes, and then cooled in cold water. The test is satisfied if no signs of turbidity are observed. All plant now used in the production of sterilised milk must be maintained and operated to the satisfaction of the licensing authority, who may require the installation of thermometers and pressure gauges. Every bottle used must be conspicuously and legibly labelled or marked " Sterilised Milk ".

The Provisional Order permitting the use of H.T.-S.T. has now been rescinded and the present Regulations allow (i) the holder method as before ; (ii) H.T.-S.T. at 161° F. or above, and (iii) any method approved by the licensing authorities. Before the war, the " holder " method, *i.e.* holding the milk at 145°-150° F., for not less than thirty minutes, was the only method permitted, and the use of H.T.-S.T. was a war emergency measure. Long before the war, however, the principle of H.T.-S.T. had been officially accepted and approved in many countries, and, in fact, plants of this character, notably the " Stassaniser " were in use here, but, of course, not licensed. The new Regulations, which display a liberal and progressive attitude, open a wide field to the dairy engineer and the plant user, all forms of pasteurising, including the " in-bottle " system, now being included subject only, as usual, to the performance being satisfactory to the licensing authority, who will endorse the operating conditions on the licence.

Another technological change is a tightening up of the cooling of pasteurised milk, the old temperature of 55° F. maximum now being replaced by a temperature of 50° F. This is obviously a keeping-quality requirement and will help to remove some of the weakness of the prescribed test (methylene blue) in hot weather.

The prescribed tests for pasteurised milk remain the same, *i.e.* the phosphatase and methylene blue tests, but alternative keeping quality tests are under review, which would require amending Regulations if adopted.

The new Regulations are rather more detailed than their predecessors but generally they are of the same order. All pasteurising plant must now be so constructed as to ensure against contamination of the milk by dust, etc., and particular reference is made to coolers.

The Regulations contain certain provisions which could not be immediately and generally complied with and their operation is postponed therefore until a future date. These are: (i) that the temperature of the medium by which the temperature of the milk is to be maintained shall be automatically controlled; (ii) from 1st October, 1954, pasteurised milk shall be delivered in bottles or containers filled in the pasteurising establishment ; (iii) all containers in which pasteurised milk is transported, exposed, or offered for sale must be securely fastened with a cap or cover overlapping the lip of the container, in a manner satisfactory to the licensing authority. The last requirement for over-lapping caps (Pasteurised Milk Regulations, 2nd Schedule, Part I, para. 7, sub-para. 3) has now been implemented. Statutory Instrument No. 1821 (1953) makes it obligatory for all bottled pasteurised milk to have over-lapping caps as from 1st October, 1954.

The Milk (Special Designations) Act 1949 limits the sale of milk by retail in areas which will be specified by the Minister of Food to those classes of milk which receive special designations. These designations are substantially the same as those provided in the Milk (Special Designations) Regulations of 1936 except that Sterilised milk is now added to this list and " in-bottle " pasteurising is approved. Accredited milk, and Standard milk in Scotland, will only be approved designations for a period of five years from the commencement of the Act. This means, in effect, that when an area is specified by the Minister of Food none other than these designated milks may be sold in that area. As this means that no raw milk may be sold other than Tuberculin Tested or Accredited milk, an area will not be scheduled until the Minister is satisfied that the facilities exist within the area for this to be accomplished, for which purpose he will consult the trade interests concerned before scheduling the area.

If the Minister considers that the existing or potential facilities are inadequate to provide the heat-treated milk that will be required, the Bill gives him power to instal and operate heat-treatment plant and provide other facilities for that purpose or to arrange with local authorities or other persons to provide such facilities.

New offences are created for infringements of certain of the conditions laid down in the licences, and for the first time these offences may be the subject of prosecution in addition to the suspension or revocation of the licence.

For the protection of the licence holder, however, he will have the right to appeal to the Minister against local authorities' proposal to revoke or suspend a licence and the Minister will place the issue before a tribunal who will consider the facts and advise the Minister accordingly.

The Milk (Special Designations) (Specified Areas) Order 1951 defined the first areas in which only designated milks may be sold. Up to June 1954, these specified areas include London and other large areas of the country covering over 50 per cent. of the population of England and Wales.

In October, 1950, an Act entitled The Food and Drugs (Milk, Dairies, and Artificial Cream) Act, 1950, was placed on the Statute Book.

This Act introduced no new legislation, but consolidated various enactments, and repealed others, so that, generally speaking, all milk law is embraced in a single Act. Milk (Special Designations) Regulations may provide for giving continuing effect to decisions, proceedings in connection with appeals, and other things made, taken or done under paragraphs (*a*) or (*e*) of subsection (1) of Section 21 of the Food and Drugs Act, 1938, which corresponded to Part I of the Third Schedule to the Act. The repealed enactments include the whole of Part II of the Food and Drugs Act, 1938, together with Part I of the First Schedule of that Act, Sections 1 to 4 of the Food and Drugs (Milk and Dairies) Act, 1944, and the whole of the Milk (Special Designations) Act, 1949. The Act may be cited, together with the Food and Drugs Acts, 1938 to 1944, as the Food and Drugs Act, 1938 to 1950.

The Act came into operation on 1 January 1951, and does not apply to Scotland or Northern Ireland.

As we go to press the Food and Drugs Amendment Bill is passing through Parliament. It abolishes the Central and County Advisory Committees (which in fact had never met) but makes only a few very minor changes in the law relating to milk.

A matter of interest in the sale of milk is concerned in the Sale of Food (Weights and Measures) Act, 1878 to 1926. Under this Act, milk must be sold by imperial measure, the correctness of the measure used being approved and stamped by the Weights and Measures Authority. In the sale of loose milk, the dipper used is so stamped, but the advent of mechanical bottling created a difficulty, since the bottle itself, in most cases, constituted the measure. To meet the requirements of the Act, every bottle would have to be individually checked, approved, and stamped by the Weights and Measures Office, a manifestly impossible procedure. After considerable discussion between the authorities and the trade a compromise was effected, which was contingent upon it being satisfactorily shown that the customer would not be prejudiced or the law flouted. The arrangement was that the bottles should not have to be stamped as measures, but that mechanical bottle filling should be performed under such conditions and control that no underfilling should occur. This is the present situation, and its satisfactory character is the result of close co-operation between the dairyman, the dairy engineer, and the bottle manufacturer. Owing to the rigid need for ensuring against automatic underfilling, the customer benefits by the arrangement since the average amount of milk per bottle is invariably in excess of the prescribed volume (*see* Bottle filling).

There are, of course, measuring devices used in mechanical filling, notably in connection with sterilised milk. In this case the capacity of the bottle cannot be used in measuring, since the bottle must be substantially oversize to allow for the expansion of the milk which occurs during sterilising. Actual measurement of milk into the bottle, therefore, is necessary.

An interesting Order is the Milk (Use of Bottles) Order, 1943, issued by the Ministry of Food. This arose out of representations made by the trade on account of the difficulties of efficient bottle washing under war-time handicaps and the public disregard of the need for proper care and protection of bottles. The Order made it an offence for a milk bottle to be improperly used, but, unfortunately, the Order is very difficult of enforcement. It lapsed in July, 1953.

Lastly, reference may be made to the position of milk dealers under the Merchandise Marks Act. Under this Act, milk sellers may not use the bottles bearing the name, initials, or other distinguishing mark of any other distributor, the penalty for a first offence being a fine of £80, or 4 months' imprisonment. This also applies to the improper use of churns and bottle-crates, unless permission has been given by the owner.

In conclusion, some reference may be made to the law regarding milk products.

Butter means the substance usually known as butter, made exclusively from milk, with or without salt, with or without the addition of colouring matter. It is an offence under the Food and Drugs Act, 1938, to sell, or offer for sale any butter containing more than 16 per cent. of water, or preservatives of any kind. A butter factory is required to be registered by the Food and Drugs Authority in accordance with the provisions of Sec. 34 of the Act of 1938. Premises cannot be registered or used as a butter factory if they form part of, or communicate, otherwise than by a highway, with any other premises which are required to be registered either as a margarine, margarine-cheese, or milk-blended butter factory, or when the business of a wholesale dealer in any of those substances is carried on.

There are no provisions relating to the labelling and marking of butter in the Act of 1938 but the marking of imported butter is subject to the Merchandise (Imported Goods) Order, 1932 (S.R. and O. 128, 1932).

Milk-blended Butter means any mixture produced by mixing butter with milk. The water content may not exceed 24 per cent. and all preservatives are prohibited. Registration of the premises where the milk-blended butter is produced is required under Sec. 34 of the 1938 Act. A further requirement is that the product must be sold under a name approved by the Ministry of Agriculture, and the amount of water it contains must be declared on the label together with a proper approved description of the article.

Cream. In the Act of 1938 any reference to milk includes cream, as it does also under the Milk and Dairies Order, 1949, so that persons selling cream, and the premises used, must be registered. Cream is subject to the provisions of Part I of the 1938 Act, in that no addition or abstraction is permitted, and that it be of " the nature, substance, and quality demanded ". No preservatives, thickening substances, or colouring matter are permitted.

In 1940 the production and sale of cream, except for butter-making, was prohibited, but this prohibition was raised in 1953, double and single cream being permitted to be sold provided their minimal respective fat contents were 48 per cent. and 18 per cent. (23 per cent. for sterilised cream).

Artificial Cream. Legally, this can only be made from milk products, and may contain no other substances, except water, which have not been so derived. Synthetic creams containing vegetable oils are not artificial cream within the meaning of the Act.

Artificial cream may not be sold for human consumption unless labelled as such (1938 Act, Sec. 27) and all containers in which the product may be carried shall be marked or labelled " Artificial Cream " in large and legible letters.

Condensed Milk. The sale of condensed milk is governed by the Public Health (Condensed Milk) Regulations, 1923-1927-1943, now incorporated in Sec. 101 of the 1938 Act. Condensed milk must contain minimal percentages of milk fat, and/or milk solids as follows :

	% *Milk fat*	% *Milk solids*
Full cream unsweetened .	9·0	31·0
Full cream sweetened . .	9·0	31·0
Skimmed unsweetened .	—	20·0
Skimmed sweetened . .	—	26·0

All tins of condensed milk must bear a label stating the nature of the contents, and the amount of milk-in-pints to which the contents are equivalent. In the case of skimmed condensed milk—whether sweetened or unsweetened—the label must also state " unfit for babies ". All these declarations demand letters of a prescribed size.

Dried Milk. Governed by the Public Health (Dried Milk) Regulations, 1923/27/43 and enforced by Sec. 101 of the Act of 1938. Full cream dried milk must contain at least 26 per cent. of milk fat. Skimmed dried milk contains less than 8 per cent. milk fat. As with condensed milk, it must be sold under a label which states its nature and its milk equivalent in letters of a definite size, and, in the case of skimmed dried milk, that it is unfit for babies.

Separated Milk. All the provisions of the Food and Drugs Act, 1938, and the Milk and Dairies Regulations, apply to separated milk. All vessels containing separated milk must be so marked in large and legible letters. Separated milk is presumed to be adulterated if the solids, other than fat, fall below 8·7 per cent.

Ice Cream. For the first time a standard of composition for ice-cream is required by the Food Standards (Ice-Cream) Order, 1951. This became operative on 1 March of that year, and the standard is as follows :

Ice-cream shall contain not less than 5 per cent. fat, 10 per cent. sugar and 7½ per cent. milk solids other than fat.

Ice-cream containing any fruit pulp or fruit puree shall either conform to the standard set forth above or, alternatively, the total content of fat, sugar and milk solids other than fat shall be not less than 25 per cent. of the ice-cream, including the fruit, fruit pulp or fruit puree, as the case may be, and such total content of fat, sugar and milk solids other than fat, shall include not less than 7½ per cent. fat, 10 per cent. sugar and 2 per cent. milk solids other than fat.

" Parev " (kosher) ice sold, offered or exposed for sale under that description shall contain not less than 10 per cent. fat and not less than 14 per cent. sugar, and the standard for ice-cream set forth above shall not apply to this product.

For the purpose of the standards prescribed above " sugar " means sucrose, invert sugar or the solids of any sweetening material derived from starch so, however, that no ice-cream shall contain less than 7½ per cent. sucrose. These standards are rather lower than the ones suggested by the Ice-cream Association of Great Britain and Ireland, which were, for a satisfactory product, not less than 8 per cent. fat and 10 per cent. non-fatty solids. The Order, however, is a provisional one made under the Emergency Laws (Continuation) Order, 1950, pending the availability of less restricted supplies of the prescribed ingredients.

It should be noted that under this Order water ices and lollies are excluded from the definition of ice cream, but are included in the definition in the case of the Ice-Cream (Heat Treatment) Regulations, 1948.

Legislation regarding ice cream rests largely in the Act of 1938, which requires registration of premises (Sec. 14) and lays down conditions which apply to all premises where ice cream is prepared or stored (Sec. 13). Under Sec. 18, a Medical Officer of Health is empowered to prohibit the sale of any ice cream he may suspect as likely to cause food poisoning, or under Sec. 37, which applies particularly to ice cream considered likely to cause epidemic diseases, such as scarlet fever, dysentery, enteric or typhoid fever, undulant fever, etc.

Whilst bacteriological standards for ice cream have long been considered desirable, none has yet been statutorily formulated, but in March, 1947, the Ministry of Health issued a directive to Local Health Authorities to take samples for bacteriological examination and submit them to a prescribed methylene blue test which grades them into four groups. The results of the tests are regarded as useful in assisting the Authorities in better exercising the powers they are given by the 1938 Act as indicated above.

By the Ice Cream (Heat Treatment) Regulations, 1946, which became effective on May 1, 1947, certain conditions were laid down for the treatment of mixes. A cold mix is required to be frozen within 1 hr. of reconstitution, or otherwise to be heated to a temperature of not less than 150° F. for 30 min., or to not less than 160° F. for 10 min., after which its temperature should be reduced, within 1½ hr., to not more than 45° F., and so kept until frozen. In all other cases the mix must be heat-treated as described above, before mixing. The finished ice cream, from either type of mix, must be kept at a temperature not exceeding 28° F. until the time of sale.

The original Regulations gave local authorities power to require the use of indicating and recording thermometers in connection with the treatment of mixes, but the operation of this was suspended until " a date to be appointed by the Minister ", by reason of the difficulty of obtaining such instruments at the time. The amending Regulation, No. 67, issued in January 1951, substitutes for the words quoted above, the words " The first day of March, 1951 ".

From that date, therefore, local authorities may insist on the use of appropriate thermometers in the manufacture of ice-cream.

To cover the whole subject of milk legislation in detail is quite beyond the scope of this article, but, as far as possible, a general survey of fundamental law has been given. For the purpose of reference the following is a list of the various principal enactments which are concerned in the production and sale of milk and its products.

List of Acts, Regulations, and Orders.

Public Health Act, 1875.
Infectious Diseases (Prevention) Act, 1890.
Public Health (London) Act.
Sale of Milk Regulations, 1901.
London County (General Powers) Act, 1904.
Public Health Acts (Amendment) Act, 1907.
London County Council (General Powers) Act, 1907.
London County Council (General Powers) Act, 1908.
Sale of Milk Regulations, 1912.
Milk and Dairies (Consolidation) Act, 1915.
Milk and Dairies (Amendment) Act, 1922.
Milk (Special Designations) Order, 1923/601.
Public Health Act, 1925.
Tuberculosis (Prevention of) Regulations, 1925.
Tuberculosis Order, 1925.
Milk and Dairies Order/1926/821 ; 1938/217 ; PRO 21/5/1943
Public Health (Imported Milk) Regulations, 1926.
Public Health (Infectious Diseases) Regulations, 1927.
Food and Drugs (Adulteration) Act, 1928.
Milk Act, 1934.
Milk (Special Designations) Order, 1934/1317.
Milk (Special Designations) Order, 1936/356 ; 1938/218 ; PRO 1941 ; 1942/771 ; 1943/1645 ; 1946/10.
Food and Drugs Act, 1938.
Sale of Milk Regulations, 1939/1417.
Heat Treated Milk (Prescribed Tests) Order, 1944/349.
Food and Drugs (Milk and Dairies) Act, 1944.
Ice Cream (Heat Treatment) Regulations, 1947/612 ; 1948/819 and 1952/815.
Milk and Dairies Regulations, 1949/1588.
Milk (Special Designations) (Raw Milk) Regulations, 1949/1590 and 1950/410.
Milk (Special Designations) (Pasteurised and Sterilised Milk) Regulations, 1949/1589 and 1950/409.
Food and Drugs (Milk, Dairies and Artificial Cream) Act, 1950.

Refs.: Bell; Swift; Richmond; Barton (1951), *Dairy Law*, London; Bibby (Sect. II) (historical); Ashford and Savage (1938) " The Food and Drugs Act, 1938 ", London; Moseley (1953), *JSDT*, 6, 130 (building requirements).

LEGUMES. A general name applied to plants of the genus *Leguminosae* which includes peas, beans, broom, trefoil, lucerne, and the clovers. The last two are of special value to the dairy farmer as they increase the nitrogen content of the soil through the nitrogen-fixing powers of the bacteria in their root-nodules. Alfalfa (lucerne) is much grown in the U.S.A. for this reason. Clovers, etc., do not thrive in acid soil so that adequate liming is necessary for their cultivation. *See* Agriculture ; Feeding.

LEICESTER. *See* Cheese, p. 196.

" LEIGH TOASTER." *See* Cheese, p. 195.

LENGTH, UNITS OF. Angstrom unit = 10^{-8} cm.; Milli-micron (mμ) = 10^{-7} cm.; Micron (μ) = 10^{-4} cm. (the unit used to describe the size of bacteria); Centimetre = 0·3937 in. *See* Definitions; Weights and measures.

LEUCOCYTES. *See* Body cells.

LEUCONOSTOC. An early name for the heterofermentive, slime-forming streptococci of plant origin. It is identical with Orla Jensen's *Betacoccus* and Streptococcus III. *See* Lactic acid bacteria.

LIGHT. Electro-magnetic waves which excite the retina and varying in length from about 4000×10^{-8} cm. (Angstrom units) (blue light) to about 7000 (red light).

The energy of light can bring about certain chemical reactions and this is why light can cause the destruction of vitamin C in milk (p. 763) and induce rancidity in butter and cheese, and reduce resazurin in milk. Milk, butter, etc., should therefore be protected from light as much as possible. *See* Auto-oxidation ; Flavours.

LIMBURGER. *See* Cheese, p. 197.

LIME. Quicklime is calcium oxide CaO, and slaked lime calcium hydroxide $Ca(OH)_2$. Both combine with carbon dioxide in the air and turn into calcium carbonate $CaCO_3$ or chalk.

Lime is used both to supply calcium to the soil and to neutralise soil acidity and is thus of the first importance to dairy farmers (*see* Legumes). On account of the high content of calcium in cow's milk, the drain on the calcium of the soil on dairy farms is very high and this calcium must be replaced. Lime is also used for neutralising brine (p. 128). *See* Calcium.

LIMITATIONS OF ANALYTICAL METHODS. *See* Accuracy ; Laboratories, organisation of.

LINERS. *See* Milking machines.

LINOLEIC ACID. 9, 12-octadecadienoic acid. *See* Fatty acids.

Refs.: Schaffer and Holm (1950), *JDS*, **33**, 865 ; Stainsby (1948), *A*, **73**, 429 (estimation) ; Bloor ; Hilditch.

LINOLENIC ACID. 9, 12, 15-octadecatrienoic acid. *See* Fatty acids.

Refs.: Bloor ; Hilditch.

LINSEED OIL CAKE. *See* Feeding.

LIPASE. *See* Cheese, p. 182 ; Enzymes ; Flavours ; Media.

LIPIDS, LIPOIDS. These are fatty substances, soluble in " fat solvents " such as ether, and insoluble in water. They can be divided into the *simple lipids*, which are the ordinary oils, fats and waxes (p. 459), and the *complex lipids* such as *lecithin* (p. 601).

The term *lipoid* is sometimes used loosely to include the lipids, and sometimes more specifically for the more stable *sterols*, carotene (*see* Vitamins) and similar substances.

Refs.: Hilditch ; Williams, K. A. ; Deuel (1951), *The Lipids*, N.Y.

LIPOLYSIS. The splitting or hydrolysis of fats by enzymes, acids, alkalis, or other means to give glycerol and fatty acids. *See* Lipase ; Enzymes, p. 448.

LIPOLYTIC ORGANISMS. Some micro-organisms can split fats, and lipolysis and proteolysis are usually correlated. The simplest medium is tributyrin agar (p. 677), but some organisms can attack this simple triglyceride, but not those in fats containing the higher fatty acids. While, therefore, tributyrin agar detects potentially or actively lipolytic organisms, it may be considered that only butter-fat media are a reliable guide for those micro-organisms actually attacking butter-fat and the use of tributyrin agar may be misleading.

Jones and Richards (1954, *SAB*, **15**, 82) have compared a number of dyes as indicators of lipolysis and conclude that night blue and victoria blue are the most suitable. Although toxic for some Gram positive organisms in the absence of fat, the toxicity is negligible in the presence of 5 per cent. butter-fat. Results ob tained by Jones and Richards are illustrated in Tables Lo 1 and Lo 2.

Refs.: Richards and El-Sadek (1949), *JDR*, **16**, 46 (fatty acids in butter).

See Auto-oxidation of fat ; Enzymes ; Media.

TABLE LO 1

The Action of Pure Cultures on Lipolysis Media (from Jones & Richards, 1952.

Cultures	Number of cultures lipolytic on				
	No. tested	*Tributyrin Agar*	*Butterfat agar treated wtih copper sulphate*	*Night blue agar*	*Victoria blue agar*
Micrococci . . .	730	647	389	390	390
Aerobic Sporebearers .	46	25	11	12	12
Yeasts . . .	51	51	2	2	2
Pseudomonas . .	31	11	11	11	11
Other Gram-negative rods	94	18	13	13	13
Streptococci . .	10	0	0	0	0

TABLE LO 2

Comparative Effect of Pure Cultures on Butterfat Emulsion and Lipolysis Media (from Jones and Richards, 1952)

Culture	*Ml. N/10 NaOH per 10 g. fat*	*Effect on lipolysis*				
		Tributyrin agar	*Butterfat agar*	*Nile blue agar*	*Night blue agar*	*Victoria blue agar*
Bact coli .	1·4	++ —	++ —	+ —	++ —	++ —
Flavobacterium .	6·0	+ +	+ —	± —	+ —	
Pseudomonas	25·0	++ +	++ +	++ ++	++ +	
Achromobacterium	28·5	++ ++	++ +	++ +	++ +	
Corynebacterium .	4·0	+ —	++ —	— —	++ —	
B. subtilis .	3·2	++ ++	++ —	— —	++ ±	— ±
B. mycoides	3·5	— —	++ —	— —	++ —	
Micrococcus	5·5	++ +	++ +	— —	++ ±	
Micrococcus	4·0	+ —	+ —	— —	++ —	++ —
Micrococcus	46·0	++ ++	++ ++	— —	++ ++	

LIQUEFYING ORGANISMS. A general term applied to those bacteria which liquefy gelatin (*see* Media). Most organisms which attack protein and fats also liquefy gelatin. The property was formerly used diagnostically but its importance in this respect has diminished. *See* Classification; Coliforms; Lactic acid bacteria.

LITERATURE OF DAIRY SCIENCE. List of Dairy Journals. A. **Scientific.** (i) ***British.*** *Journal of Dairy Research.* Three times a year. Cambridge University Press. 1929—. 40s. a volume. Publishes results of original research in dairy science and cognate subjects, also reviews of the progress of dairy science.

Dairy Science Abstracts. Quarterly. Commonwealth Bureau of Dairy Science, Shinfield, Reading. 1939—. 50s. a volume. Abstracts are collected from a large number of periodicals in many languages.

(ii) ***Foreign.*** *Journal of Dairy Science.* Monthly. American Dairy Science Association, North Queen Street and McGovern Ave., Lancaster, Pennsylvania, U.S.A. (British subscriptions to Baillière, Tindall and Cox, Henrietta St., Covent Garden, London, W.C. 2.) 1917—. 84s. a year. Publishes original articles, abstracts, and Society proceedings.

Kieler Milchwirtschaftliches Forschungsberichte. Bimonthly. (24*b*) Kiel, Hermann-weigmann Str. 3/11 Germany. D.M. 40 a year.

Le Lait : Revue générale des questions laitières (Milk). Bimonthly. 16 rue Spontini, Paris (16e). 1921—. 3000 fr. a year. Publishes original articles, reviews, and abstracts.

[1] *Milchwirtschaftliche Forschungen* (Dairy Research). Irregular. Julius Springer, Berlin, Germany. 1923-43. Price per number varies. Original articles and abstracts.

Die Milchwissenschaft (Dairy Science). Monthly. Verlag Hans Carl, Breitegasse 58-60, Nürnberg, Germany. 1946—. RM. 4.50 per number. Original articles and abstracts on the chemistry, bacteriology, physics, and machinery of dairying.

B. **Technical.** (i) ***British.*** Australia. Commonwealth Bureau of Census and Statistics. Summary of Dairying. Monthly. Commonwealth B.C.S., Canberra, Australia. 1937—. Mimeographed statistics of dairy production.

Australian Dairy Review. Monthly. Australian Dairy Produce Board, Melbourne, Australia. 1933—. 6s. a year.

Australian Journal of Dairy Technology. Quarterly. Australian Society of Dairy Technology, Box 4313, Melbourne, C.1, Victoria, Australia. 1946—. 21s. a volume of four numbers.

[2] *Australian Milk and Dairy Products Journal.* Monthly. 10 O'Connell St., Sydney, New South Wales, Australia. 10s. 6d. a year in the British Empire, 12s. 6d. outside.

Butterfat and Solids. Quarterly. 10 O'Connell St., Sydney, New South Wales, Australia. 1941—. 15s. a year in the British Empire, 20s. outside.

Canada. Dominion Department of Agriculture. *Dairy Produce Market Report.* Weekly. Dominion Department of Agriculture, Ottawa, Canada. Free. Mimeographed statistics.

Canadian Dairy and Ice Cream Journal. Monthly. B. L. Smith Pub. Co., 122 Richmond St. West, Toronto, Canada. 1921—. $2 in British Empire, $3 outside.

Dairy Industries. Monthly. 24 Bride Lane, Fleet St., London, E.C. 4. 1936—. £1 10s. a year. Incorporates Ice Cream Manufacture and Dairy Technology.

Dairy Products Review. Monthly. Dairy Products Division, Department of Agriculture, Ottawa, Canada. 1920—. Free. Mimeographed statistics.

Home Farmer. Monthly. Milk Marketing Board, Thames Ditton, Surrey. 1934—. Free. The Official Organ of the Milk Marketing Board.

Indian Journal of Dairy Science. 1948—. 20s. a year. Official Organ of the Indian Dairy Science Association.

Journal of the British Dairy Farmers' Association. Formerly annual. Since 1942 irregular. British Dairy Farmers' Association, 17 Devonshire St., London, W. 1. 1877—. Free to members of the Association.

Journal of the Society of Dairy Technology. Quarterly. Society of Dairy Technology, 17 Devonshire St., London, W. 1. 1947—. 40s. a volume, free to members of the Society. Reports of papers and discussion at meetings of the Society and its branches.

Milk Industry. Monthly. 24 Bruton St., London, W. 1. 1921—. 20s. a year.

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[1] Ceased publication in 1943.

[2] Ceased publication in 1951.

Monthly Dairy Report, Ontario Department of Agriculture. Monthly. Ontario Department of Agriculture. Toronto, Ontario, Canada. 1938—. Free. Statistics of dairy production.

New Zealand Dairy Exporter. Monthly. N.Z. Dairy Produce Exporter Co. Ltd., P.O. Box 1001, Wellington, New Zealand, 1925—. 12s. 6d. ; 20s. abroad a year. Official organ of the N.Z. Dairy Board and other dairy associations.

Proceedings of the National Dairy Association of New Zealand. Annual. National Dairy Assoc. of New Zealand Ltd., Wellington, N.Z. 1931—. Free.

Québec Laitier. Monthly. Association des Techniciens en Industrie laitière du Québec, Saint-Hyacinthe, Quebec. 1942—. 7s. a year.

South African Dairy Industries Journal. Monthly. South African Dairy Industries Journal (Pty.) Ltd., Beresford House, Main St., Johannesburg, South Africa. 1947—. 15s. a year.

South African Dairyman. Monthly. Dairy Publications Ltd., 805 Maritime House, Loveday St., P.O. Box 7453, Johannesburg, South Africa. 1939—. 10s. 6d. a year.

B. (ii) ***Foreign.*** *Association Bulletin,* Milk Industry Foundation, Irregular. Milk Industry Foundation, 1001—15th St., N.W., Washington, 5, D.C., U.S.A. 1938—.

American Dairy Products Review. Monthly. 92 Warren St., New York City, 7, N.Y., U.S.A. 1938—. $6 a year.

American Milk Review. Monthly. 92 Warren St., New York City, 7, N.Y., U.S.A. $6 a year.

Boletim do Leite e seus Derivados. Monthly. Sr Otto Frensel, Rio de Janeiro, Caixa Postal 1283, South America. 4th ser., 1947—. 50 S. Amer. dollars a year.

Deutsche Molkerei-Zeitung (German Dairy News) Deutsche Molkerei-Zeitung, Kempten im Algäu, Bavaria, Germany. 1943—. £4 7s. 6d. a year.

Hoard's Dairyman. Twice a month. Fort Atkinson, Wisconsin, U.S.A. 1885—. $1 a year. Dairy farming paper.

Ice Cream Review. Monthly. Olsen Pub. Co., 1445 N. 5th St. at W. Cherry, Milwaukee, Wisconsin, U.S.A. Vol. 31 in 1948. $3 a year.

Ice Cream Trade Journal. Monthly. 304 E. 45th St., New York, N.Y., U.S.A. 1905—. $3 a year.

Industrie Laitière (Dairy Industry). Monthly. Association Laiterie Française, 17 rue de Valois, Paris, le France. 1876—. 625 fr. a year.

[1] *International Association of Ice Cream Manufacturers. Report of Proceedings of the Annual Convention.* Annual. I.A.I.C.M., Barr Building, Washington, D.C., U.S.A., Vol. 41 in 1941. Free to members.

Journal of Milk and Food Technology. Bimonthly. 374 Broadway, Albany 7, N.Y., U.S.A. 1937—. $5.50 a year.

Karjantuote (Dairy Husbandry). Fortnightly. Helsinki, Finland.

Karjatalous (Dairy Products). Fortnightly. Helsinki, Finland.

Il Latte, Monthly. Via Ampère, 26, Milan, Italy. 2000 lire a year.

Maelkeritidende (Dairy News). Weekly. Andelsbogtrykkeriet, Odens, Denmark. Vol. 61 in 1948. 33s. a year.

Meieriposten (Dairy Mail). Weekly. Norsk Meierifolks Landsforening, Grensen 3 vii, Oslo, Norway. Vol. 37 in 1948.

Mejeritidskrift (Dairy Journal). Quarterly. Finlands Svenska Andelsförbund, Unionsgatan 18, Helsinki, Finland. 1939—.

Milk Board Journal, N.S.W. Monthly. N.S. Wales Milk Board, 310 George St., Sydney, N.S. Wales, Australia. Free.

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[1] Publication suspended.

Milk Dealer. Monthly. Olsen Publishing Co., 1445 N. 5th St., at W. Cherry, Milwaukee 12, Wisconsin, U.S.A. 1912—. $3 a year.

Milk Plant Monthly. Monthly. National Milk Publishing Co. Inc., 327 S. LaSalle St., Chicago, Illinois, U.S.A. 1912—. $4 a year.

Molkerei- und Kaserei-Zeitung (Dairy and Cheese Factory News). Monthly. Th. Mann, Kommandit-Ges., Hildesheim, Germany, 1950—.

Molkerei-Zeitung (Hildesheim). (Dairy News). Twice weekly. W. Niewerth, Hildesheim, Germany. N.s. 1947—. D.M. 28.80.

Il Mondo del Latte. Monthly. Via Pietro Verri, 8 Milan, Italy. 5000 lire a year.

Netherlands Milk and Dairy Journal. Quarterly. D. B. Centen's Uitgevers-Maatschappij N.V., Sarphatikade 12, Amsterdam (C). 1947—. 10 florins a year.

New York State Association of Milk Sanitarians, Annual Report of Proceedings. Annual. Walter D. Tiedeman, Sec.-Treas., New York State Department of Health, Albany, New York, U.S.A. 1927—. Free to members.

Nordisk Mejeri-tidsskrift (Scandinavian Dairy Journal). Monthly. Robert Hansen, Tornestykket 3, Vantose, Copenhagen, Denmark. 1935—. 17s. 6d. a year.

Officeel Orgaan van de Algemeene Nederlandsche Zuivelbond (Official Organ of the Central Dairy Union). Fortnightly. Algemeene Nederlandsche Zuivelbond, Van de Spiegelstr., 16 The Hague, Holland. Vol. 40 in 1948. 30s. a year.

Osterreichische Milchwirtschaft (Austrian Milk and Dairy Industry). Twice Monthly. Österreichischer Agrarverlag, Bankgasse 3, Vienna 1, Austria. 1946—. $13.20 a year.

Proceedings of the State College of Washington Institute of Dairying. Annual. State College of Washington Agricultural Experiment Station, Pullman, Washington, U.S.A. 1928—. Free. Mimeographed.

Schweizerische Milchzeitung (Swiss Milk Journal). Weekly. Kuhn & Co., Schaffhausen, Switzerland. Vol. 72 in 1946. 42s. a year.

Southern Dairy Products Journal. Monthly. Fred H. Sorrow, Marietta. Georgia, U.S.A. Vol. 40 in 1947. 40s. a year.

Spel (Service Provisoire de l'Economie Laitière). Monthly. 7 rue Scribe, Paris, France. 1946—. 350 fr. a year.

Svenska Meieritidningen (Swedish Dairy News). Weekly. Sture Tyrberg, Kungsgatan 24, Malmö, Sweden. Vol. 40 in 1948. 27s. a year.

Zuivelbereiding en Handel (Dairy Manufacture and Trade). Weekly. Maatschappij "C. Misset", N.V., Doetinchem, Holland. Vol. 58 in 1948. 11s. a year.

C. **Popular.** (i) ***British.*** *British Goat Society Monthly Journal.* Monthly. British Goat Society, Diss, Norfolk. 1908—. Membership subscription £1 a year, 1s. a number to non-members.

Dairy Farmer. Monthly. 10 Tavern St., Ipswich. 1929—. 11s. a year.

Dairyman. Monthly. 9 Eden St., London, N.W. 1. 1879—. 20s. a year.

Indian Dairyman. Monthly. Hosur Rd., Bangalore 1, India. 1949—. 10s. a year.

Milk Messenger. Monthly. Cherry-Burrell Ltd., Power Rd., Chiswick, London, W. 1924—. Free.

[1] *Milk Trade Gazette.* Monthly. Tudor Press, Tudor House, 75 Carter Lane, E.C. 1930-Feb. 1941.

(ii) ***Foreign.*** *American Milk Review.* Monthly. Urner-Barry Co., New York, N.Y., U.S.A. 1938—. $4.00 a year.

Certified Milk. Monthly. Box 806, Scranton, Pennsylvania, U.S.A. 1926—.

Dairy Research Digest. Quarterly. Louisiana Agricultural Experiment Station, Baton Rouge, Louisiana, U.S.A. 1943—. Free. Summary of important research findings by the Dairy Research Department and of work from other stations having a direct application to Louisiana conditions.

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[1] Publication suspended.

Dansk Mejeritidende (Danish Dairy News). Twice a month. Sølvgade 38, Copenhagen, Denmark. Vol. 45 in 1948. 8 Kr. a year.

Journals not Exclusively Devoted to Dairying but Containing Relevant Articles. *Agricultural Gazette of New South Wales; Agricultural Progress; Agriculture, Journal of the Ministry of Agriculture; American Journal of Public Health; Annals of the Royal Agricultural College, Sweden; Applied Microbiology; Ayrshire Cattle Society's Journal; Analyst.*

Biochemical Journal; Biochemische Zeitschrift; Boletim de Industria Animal; British Friesian Journal; British Society of Animal Production, Report of Proceedings; British Medical Journal; Bulletin of the World Health Organisation.

Canadian Journal of Public Health; Canadian Journal of Nutrition; Canadian Journal of Research [1]; *Chemistry and Industry.*

Empire Journal of Experimental Agriculture.

Farmer and Stockbreeder; Farmers Weekly; Farming in South Africa; Food; Food Industries (New York); *Food Manufacture; Food Research; Food Technology.*

Guernsey Breeder's Journal (London); *Guernsey Breeders' Journal* (U.S.A.).

Hoard's Dairyman; Holstein-Friesian World.

Indian Farming; Indian Journal of Veterinary Science and Animal Husbandry; Analytical Chemistry; Industrial and Engineering Chemistry (ind. ed.); *International Review of Agriculture; International State College Journal of Science.*

Jersey Cow; Journal of Agricultural and Food Chemistry; Journal of Agricultural Research; Journal of Agricultural Science; Journal of Animal Science; Journal of the Association of Official Agricultural Chemists; Journal of Bacteriology; Journal of Biological Chemistry; Journal of the Council for Scientific and Industrial Research, Australia; Journal of Comparative Pathology and Therapeutics; Journal of the Department of Agriculture for Eire; Journal of the Department of Agriculture of South Australia; Journal of the Department of Agriculture, Victoria, Australia; Journal of the Department of Agriculture, Western Australia; Journal of the Farmers' Club; Journal of General Microbiology; Journal of Hygiene; Journal of Nutrition; Journal of the Red Poll Breed; Journal of the Royal Swedish Academy of Agriculture; Journal of the Royal Agricultural Society of England; Journal of the Science of Food and Agriculture.

Kungl. Landbruksakademiens Tidskrift.

Kungl. Landbrukshögskolans Annaler.

Laboratory Practice; Lancet; Landbouwkundig Tijdskrift; Landtmannen Tidskrift für Landtman; Landwirtschaftliches Jahrbuch der Schweiz.

Mededeelingen der Landbouhoogeschool, Gent.

New Zealand Journal of Agriculture; N.A.A.S. Quarterly Review; New Zealand Journal of Science and Technology; Norsk Landbruk; Northern Dairy Shorthorn Breeders Review; Northern Ireland Monthly Report of the Ministry of Agriculture; Nutrition Abstracts and Reviews.

Ohio Bi-monthly Bulletin; Onderstepoort Journal of Veterinary Science and Animal Husbandry.

Proceedings of the Society for Applied Bacteriology [2]; *Proceedings of the Society for Experimental Biology and Medicine.*

Quarterly Bulletin. Michigan Agricultural College; Queensland Agricultural Journal; Queensland Journal of Agricultural Science.

Revista de la Asociación Argentina de Dietologia; Revista Española de Lecheria; Rhodesia Agricultural Journal.

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[1] Now published as six separate journals: *Canadian Journal of Botany; Canadian Journal of Chemistry; Canadian Journal of Medical Sciences; Canadian Journal of Physics; Canadian Journal of Technology; Canadian Journal of Zoology.*

[2] Now *Journal of Applied Bacteriology.*

Schweizerische Landwirtschaftliche Monatshefte ; Scientific Agriculture[1] ; *Scientific Proceedings of the Royal Dublin Society; Scottish Agriculture; Scottish Farmer; Shorthorn Journal.*

Tasmanian Journal of Agriculture; Trabajos del Instituto de Biologia Animal; Transactions of the Highland and Agricultural Society of Scotland; Veterinary Journal; Veterinary Record; Welsh Journal of Agriculture.

Zeitschrift für Lebensmittel-Untersuchung und Forschung; Zentralblatt für Bakteriologie, etc. Abt. II.

LITMUS MILK. *See* Classification ; Lactic acid bacteria ; Media.

LITRE. The scientific unit of volume equal to 35·196 fl. oz. or 61·028 cu. in.

LITTLE PLATE METHOD. *See* Frost little plate method.

LIVE WEIGHT. *See* Management of cattle ; Pigs.

LLAMA MILK. *See* Mammals.

LOGARITHMIC PHASE. *See* Phase.

LONG MILK. *See* Ropy milk.

LONGEVITY OF COWS. *See* Management of cattle.

LONGEVITY OF MICRO-ORGANISMS. *See* Cheese ; Freeze Drying ; Growth ; Lactic acid bacteria ; Survival ; Stability.

LOOSE MILK. Milk in hand cans or unsealed cans. *See* Legal aspects.

LOSSES. *See* Costings ; Wastage.

LUMPINESS. *See* Condensed milk ; Evaporated milk ; Sweet curdling.

LUXEMBOURG.

Ref.: Neu (1949), *IDC*, 4, 269.

LYMPH. An almost colourless, coagulable fluid in the lymphatic system.

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[1] Now *Canadian Journal of Agricultural Science.*

M

M. Chemical shorthand for molar (p. 748).

μ (mu). An abbreviation for *micron* or $\frac{1}{1000}$ millimetre.

MACCONKEY'S MEDIUM. *See* Coliforms and Media.

MAGNESIUM. A dibasic element present in milk to the extent of about 0·02 per cent. From the point of view of acid-base balance it behaves similarly to calcium. *See* Acid-base equilibria ; Constituents.

MAILLARD REACTION. *See* Browning of milk ; Milk powder.

MAIZE. Maize is a valuable feeding stuff for dairy cows although it is only grown in this country by a few enthusiasts. It is very popular in the U.S.A. where it is known as corn. *See* Feeding.

MALLEABILITY. The capacity for being beaten out into sheets.

MALTA.

Ref.: Falzon (1949), *IDC*, **5**, 157.

MALTA FEVER. A synonym for undulant fever. *See* Abortion ; Diseases.

MALTED MILK. Malted milk is a nourishing drink which is not very common in this country. It is prepared by " combining whole fresh clean milk with the liquid separated from a mash of ground barley malt, and whey with or without the addition of sodium chloride, sodium bicarbonate and potassium bicarbonate in such a manner as to secure the full enzymic action of the malt extract and by removing water. The finished product usually contains not less than 7½ per cent. fat and not more than 3½ per cent. moisture ". (U.S.A. Federal Specification quoted by Whittier and Webb.) Typical analyses are given by Cox as follows:

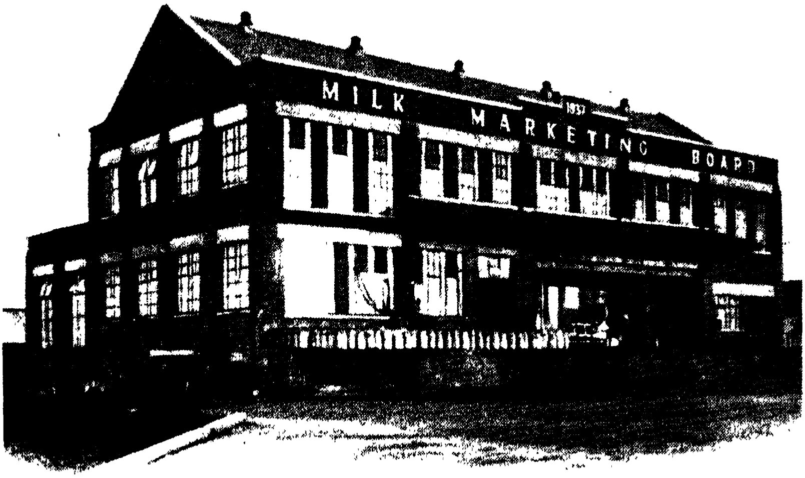
TABLE MI 1

	1	2	3	4	5	6
	%	%	%	%	%	%
Moisture	3·48	3·25	3·41	3·64	3·29	5·83
Fat	9·31	7·91	7·42	7·50	8·43	8·17
Ash	5·28	3·49	3·43	4·30	4·04	3·30
Proteins	20·07	14·63	10·23	19·95	15·06	15·06
Lactose	12·72	10·95	11·89	16·93	24·71	12·29
Other reducing sugars as maltose	37·88	45·45	45·00	46·82	34·75	37·16
Sucrose	9·52	—	—	—	—	—
Non-reducing sugars . .	—	14·30	18·60	0·80	9·70	19·80

Ref.: Whittier and Webb; Cox.

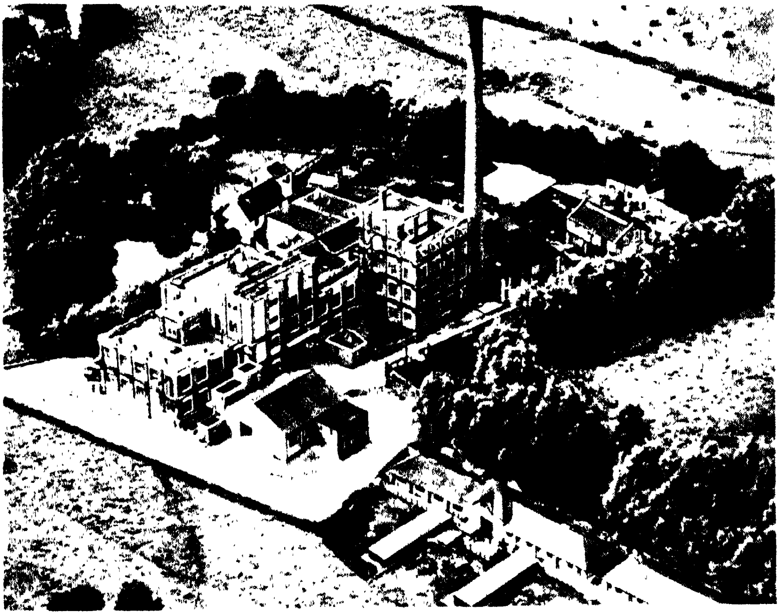
MALTY FLAVOUR. Malty taint in milk, also called burnt or caramel flavour, is not common, but when it occurs it may be commercially disastrous. Outbreaks of malty milk occur at isolated intervals in widely separated areas and at different times of the year, but especially during hot weather. Both smell and taste are affected ; the milk is quite unpalatable and therefore unsaleable for human consumption. Butter made from the cream also has the same taint. When used for cheesemaking the texture and taste of the final product are impaired.

Hammer and Cordes (*Res. Bull. Iowa Agric. Exp. Sta.*, 1921, No. 68) have described this phenomenon and found that it was caused by an organism which closely resembled *Streptococcus lactis* (Lister). In 1918 Leitch (*W. Scot. Agric. Coll. Tech. Bull.*) isolated from a commercial starter and from a sample of naturally



[*By courtesy of the Milk Marketing Board.*

FIG. MC 1.—*A Typical Creamery showing the Receiving Platform.*



[*By courtesy of Aplin & Barrett Ltd.*

FIG. MC 2.—*Aerial View of Factory, Incorporating Spray Drying Plant.*

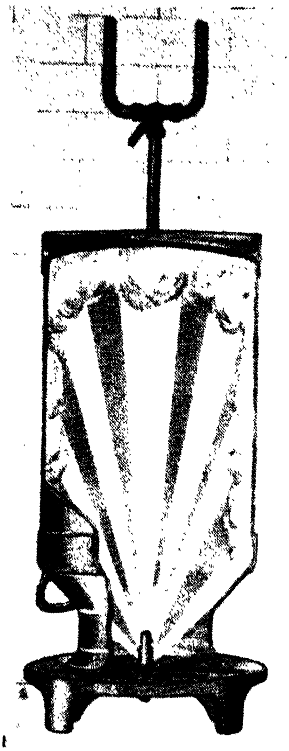
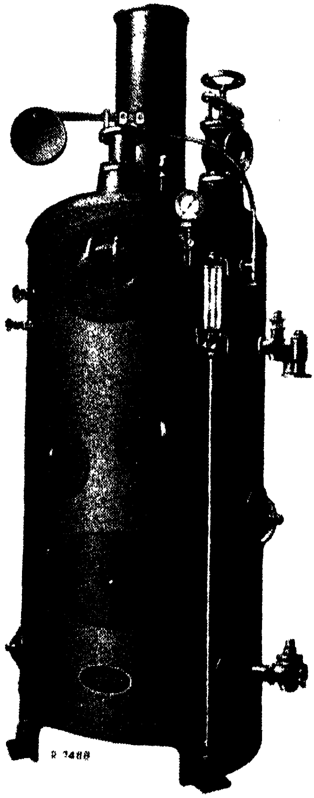


FIG. MC 3.
Can Washing and Steam Sterilising



[*By courtesy of Ruston Hornsby Ltd.*

FIG. MC 4.—" *Economic* " *Type of Boiler.*

fermented goat's milk organisms of the *Str. lactis* type which produced burnt or caramel flavour in milk. Later (*Scot. J. Agric.*, 1934, **17,** 293) he found that not only was the organism of external origin (as had hitherto been assumed) reaching the milk by faecal contamination or from infected utensils or stagnant water in pastures, but was often present in the milk before leaving the udder. He also found that this flavour showed considerable fluctuation, being present in milk from the same cows to a greater extent on some days than others. Hammer and Baker (*Res. Bull. Iowa Agric. Exp. Sta.*, 1926, No. 99) stated that malty flavour in milk was caused by *Str. lactis*. var. *maltigenes*, but Tracy and Ramsey (*JDS*, 1931, **14,** 457) said that it may also be produced by certain micrococci of the *aureus* type. Acid-formers are said to retard the development of the taint and *Bacillus subtilis* to intensify it.

TABLE Ma I

EXAMINATION OF RINSES FROM COWS' UDDERS, DAIRY UTENSILS, ETC., BEFORE AND AFTER CHLORINATION

Rinses from	*Malty smell at* 30° *C.* (*days*)					
	Before chlorination			*After chlorination*		
	1	2	3	1	2	3
Milkers' hands	+ + +	+ + +	+	—	—	—
Udders	+ + +	+	+	—	?	—
Pails	+ + +	+ + +	+	?	?	—
Churns	+ +	+ +	sl.	?	—	—
Strainer	+ + +	+ +	sl.	—	—	—
Control	—	—	—	—	—	—

? — doubtful. sl. - slight. + = definite. + + = strong. + + + = very strong.

TABLE Ma II

EXAMINATION OF RINSES FROM MALTY MILK CHURNS MADE AFTER THE USUAL STEAM STERILISATION AND AFTER ADDITIONAL SCRUBBING WITH HYPOCHLORITE

Churn no.	*Malty smell at* 30° *C.* (*days*)					
	Steam sterilisation			*S.s. plus hypochlorite*		
	1	2	3	1	2	3
1 [1]	—	sl.	bad	—	—	? sour
2 [1]	+ +	+ sour	sl.	—	—	—
3 [2]	+	sour	bad	—	—	—

S.s. Steam sterilisation. ? = doubtful. sl. — slight. + = definite. + + = strong.

[1] Clean churn rinsed for 20 min. with malty milk.

[2] Churn which contained malty milk on delivery at the dairy.

Davis, Jones, Wilby and Cranfield ((1945), *SAB*, p. 47), found that an outbreak of malty milk could be effectively controlled by rigorous attention to hygiene, including chlorination of milkers' hands, cows' udders, and all milking utensils, combined with efficient cooling at the farm to delay the development of malty flavour (Tables Ma I and II). Pasteurisation kills the organisms and early treatment prevents the appearance of the taint in the processed milk.

Refs.: Hammer; Virtanen and Nikkilä (1947), *JDR*, **15,** 89 (starter and butter)

MAMMAE, MAMMARY GLANDS. *See* Milk secretion.

MAMMALS, MILK OF. The milk of any one mammal is of a composition most suitable for the nourishment of the young suckling until such time as it can feed on other foods. Its composition is therefore influenced by such factors as increase in growth rate, digestive mechanisms, requirements in minerals, energy and vitamins, etc.

The first milk after parturition is of quite a different composition from the later milk and is termed colostrum (p. 272). In the cow, the secretion becomes approximately normal in 3 days and normal in about 15 days. Colostrum is rich in globulins and probably exerts a powerful immunological effect.

The duration of normal lactation varies with different mammals and in *late lactation* the milk changes chemically to resemble in many ways *abnormal milk* or mastitis milk.

TABLE Mm I

Animal	*Fat*	*Lactose*	*Casein*	*Albumin, etc.*	*Ash*
Ass	1·4	6·1	0·75	1·2	0·5
Buffalo	6·0	4·5	3·8	0·7	0·75
Camel	3·0	5·5	3·5	0·4	0·77
Cat	4·7	4·8	3·6	3·2	0·6
Cow	3·75	4·75	3·0	0·4	0·75
Dog	11·0	3·2	5·0	2·6	0·73
Elephant	19·5	8·8	3·1[1]	—	0·65
Fox	6·3	4·6	6·3[1]	—	0·96
Goat	6·0	4·3	3·3	0·7	0·84
Guinea pig	7·1	2·1	4·7	0·5	—
Hippopotamus	4·5	—	—	—	—
Human	3·7	6·4	0·9	1·2	0·3
Llama	3·1	5·6	3·0	0·9	0·8
Mare	1·1	5·8	1·3	0·7	0·3
Mule	1·7	5·3	2·1[1]	—	0·4
Pig	6·5	3·3	3·7	1·5	1·0
Porpoise	48·0	1·3	11·2[1]	—	0·6
Rabbit	16·7	2·0	8·1	2·2	—
Reindeer	17·1	2·4	8·4	1·7	1·5
Sheep	9·0	4·7	4·6	1·1	1·0
Whale	43·0	—	7·1[2]	—	0·45
Zebra	4·8	5·3	3·0[1]	—	—

[1] — total protein. [2] — protein plus sugar.

Typical analytical figures for the milk of the more common mammals are given in Table Mm I as percentages. *See* Human milk; Nutritive value.

Refs.: Davies; Richmond; Rogers; Anantakrishnan (1941), *JDR*, **12**, 119 (ass); Knowles and Watkins (1938), *JDR*, **9**, 153 (goat); Linton (1937), *JDR*, **8**, 143 (mare)

MANAGEMENT OF CREAMERIES. Of the many sections of the milk trade perhaps the title " Creamery Management " covers more subjects than any other. Creameries may handle from a few hundred gal. per day up to as much as 50,000. Typical creameries are illustrated in Figs. MC 1 and 2. It does not follow that the larger the creamery the harder the management: often the reverse is the case. Methods of creamery management have during the last 25 years changed considerably, but certain fundamental principles still remain. In this article, the most important fundamentals will be considered.

What type of man takes up creamery management as a career ? Why does he do so, and what are the qualities necessary to be successful ? Many present-day managers are the product of the Dairy Schools. A Dairy School training up to at least N.D.D. standard is very desirable, but not essential, provided the person is able to grasp the fundamentals of bacteriology. An efficient manager need not have a deep knowledge of bacteriology, but he must have a sound basic knowledge to know why peculiar things happen to milk, and what the remedy is. No man who is not prepared to work hard should embark on a creamery career. He must be prepared to work 7 days per week if necessary, and on occasions far into the night, perhaps for months on end. Any prospective manager not prepared to do this would be well advised to try other fields of activity. Some managers just drift into the business and quite often are successful. I would not advise women to take up management, as there are other branches of the industry which suit them better. Many managers would find it difficult to say how they became managers. Many come from the ranks of farms inspectors and laboratory staff. Both make good jumping-off grounds. The qualifications of a good manager are roughly as follows :

(1) He must be a good mixer and able to satisfy that most important person—the milk producer. A good manager is a man who knows his farmers and can handle ticklish problems of short measure and sour milk in such a way as to satisfy both his firm and the farmer concerned. When I hear a farmer quoting the manager's name as his buyer, rather than the firm, I know that the firm have a man of some worth. At the present moment all movement of milk between buyers is government controlled, but should free buying come to us again the manager who knows his farmers will be a great asset to his firm. The old days of free buying were perhaps the most strenuous days, but if successful, were something to look back on with some degree of pride. However efficient a manager may be inside his dairy, he is no use if he is at loggerheads with his producers. A dairy with a good farm intake is absolutely essential. One might suggest that a manager's shortcomings could be overcome by the appointment of a farms inspector or adviser ; such is not the case in our experience.

(2) A successful creamery manager must be able to handle his staff well. He must not only choose a good staff, but he must see that the staff are treated in such a way that they value their jobs. Men or women who have good jobs and do not value them are better dispensed with. A few " grousers " on a staff are a source of contamination to the good members of the staff. A manager cannot do too much for members of his staff who are pulling their weight. He will be amply repaid for any little consideration shown.

(3) A good manager must have started on the bottom rung of the ladder and have worked his passage through the business. A season or two making cheese brings one nearer to milk than anything else, and certainly shows one what the word " work " implies. It has always been my view that staff respect the manager if they know that he can do any job better than they can. A successful manager always sets a high standard in his dairy. If one walks into a dairy and finds the floor strewn with milk, one can say that a change in management is needed. A dairy should be clean, well painted, and all brass and copper polished. Smoking in the dairy should be prohibited. The boiler-house is a place where order should prevail, but quite often the reverse is the case. The appearance of the staff is an indication of the manager's ability—dirty men or women in dirty clothes are never associated with good management. If a manager makes up his mind to set a high standard and persists until he gets it, he will be amply repaid for his efforts by his employers and friends in the trade. If he finds that it is easier to take the simple way and let things slide, he will be heading for possible dismissal or continuous worry and trouble.

Milk Reception. There are two aspects of this subject : (i) checking the *quantity* from the farmer ; (ii) checking the *quality*.

There are two methods of checking the quantity—one can weigh the milk in a government-stamped self-indicating dial machine, or one can check the measure in the cans by tipping into a government-stamped imperial measure. The first method is very efficient, and is usually done by tipping the contents of each farmer's churn, or churns, into a pan slung under the weighing machine. These machines are usually 500 or 1000 lb. capacity, and can have a gallonage and quart dial fitted in addition to the pounds dial. In fixing the machine, always go to the trouble and expense of sinking it low enough to ensure that one man can tip the churns: the tipping bar should be about 6 in. above the level of the floor on which the churns are standing. Always ensure that the drainings are returned to each producer's weighing or otherwise you will be rightly accused of sharp practice.

The other method in use is to inspect the milk in each churn, and if not satisfied with the measure, tip into a stamped measure. This method is simple and rather quicker than weighing. (Fig. Ti 1.)

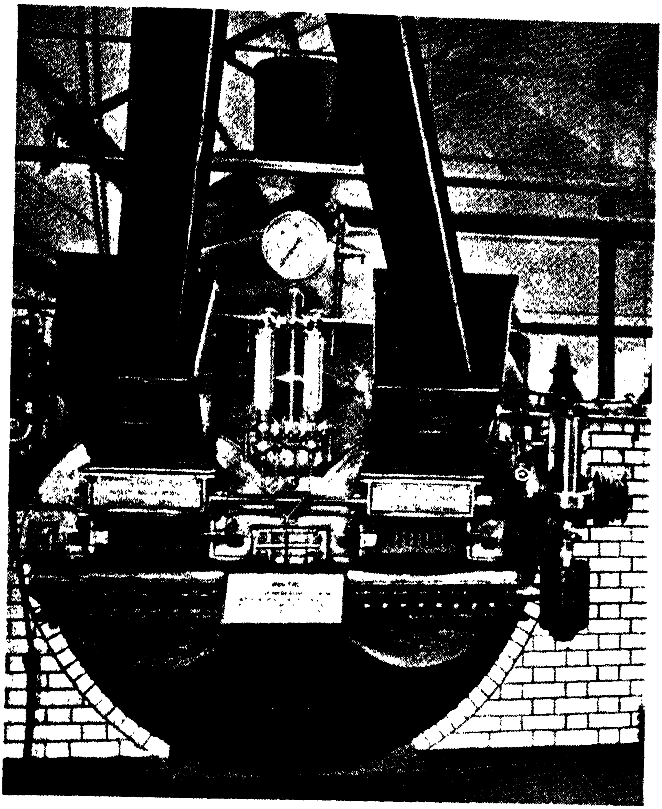
Checking for quality is, without doubt, the corner stone of the whole job. If your checkers are inefficient or careless all your subsequent efforts are wasted. You must pick a man, or men, who have the gift to analyse smells, and who realise the importance of their job. Put them on a pedestal and pay them better than the ordinary rate: you will get your money back a hundred fold. Choose a man who is likely to stop with you for good, and once having picked your man you must ensure that his work is married to the laboratory. There must be good relationship and confidence between the checkers and the laboratory: you must encourage this by all the means in your power. The checker, if suspicious of a churn of milk, puts it on one side, and the laboratory people come along and subject the milk to the resazurin test. This is a 10 min. colour test and appears to be quite effective. My own view is that if the checker is not satisfied with the result of the laboratory test, he should have the last say as to whether it is tipped or not. The checker is the sole arbiter on rejecting milk on taint. I would suggest that in ordinary conditions milk with a resazurin test of 3½ and under (10 min. test), should be rejected. Do not be tempted to lower the standard to please anyone, and do not be misled into believing that any milk is good enough for manufacture. Always use your best milk for manufacture. Your products have to stand the test of time, whereas your liquid milk is consumed within a few hours. No one has ever succeeded in turning out a first-class product from second-class raw material. *See* Platform testing.

Churn Washing. Here is a subject which is of hardly less importance than careful checking. There are two methods of washing cans, *i.e.* hand washing and machine washing.

(i) ***Hand washing.*** This can be just as efficient as machine washing, provided always that the operator has the right tackle with which to work, and is, above all, conscientious. Do not expect a man washing cans to have a big output of sterile cans. The apparatus necessary is as follows: (*a*) Two steaming blocks each with a water rinse and live steam. (*b*) Washing-up tank with water and steam. (*c*) One turks-head brush. (*d*) One hand brush. (*e*) One steaming cabinet for lids.

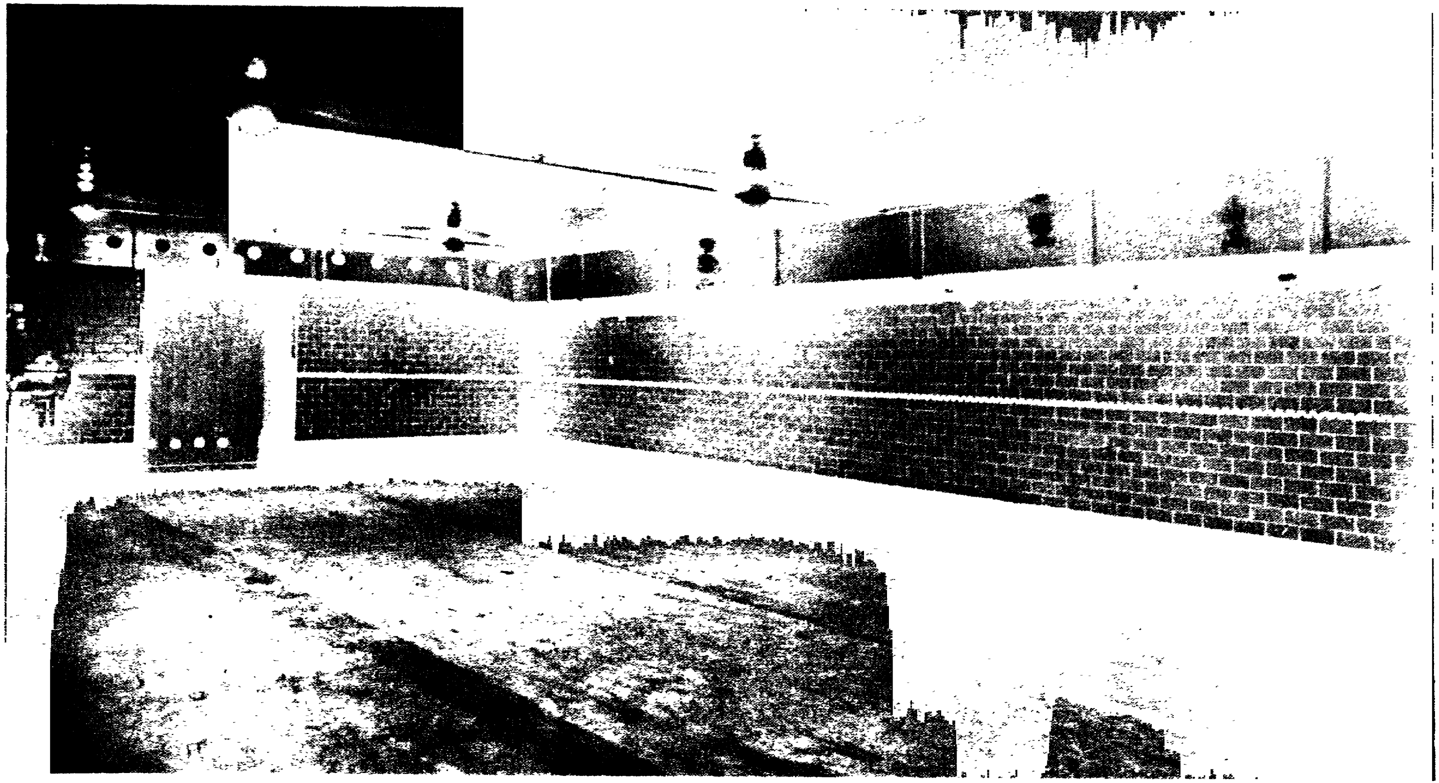
The man will first take the lid off the can, wash it in warm soda water, rinse in clean water and place it in the steriliser. He will then wash the outside of the churn with the hand brush and then the inside with the turks-head brush. The churn is then inverted on the steaming block and the rinse turned on. After 5 sec. rinsing, the steam is turned on for *not less* than 30 sec. The churn is then taken off and the lid left off. The churn, if it has been hot enough, should dry out before the lid is put on. The lids, say twelve at a time, are sterilised in a cabinet for 1 min., and when cooled off are put on the churns. Everything depends on the zeal of the worker to do his job properly. A bonus on results is a good way of keeping the worker interested in his job.

(ii) ***Machine washing.*** There are two types of machine in general use—the rotary and the tunnel or straight-through type. The advantage of the rotary type over the tunnel type is that it will wash almost any type of can, and it takes



[*By courtesy of John Thompson* (*Wolverhampton*) *Ltd.*

FIG. MC 5.—" *Lancashire* " *Dish Ended Boiler.*



[By courtesy of Newhills Insulation Co. Ltd.

FIG. MC 6.—*Cold Room.*

up less room (Figs. Cu 1 and 2). Some are hand turned and some are turned continuously by power, and some are intermittent and self-centering over the jets. The big disadvantage of the rotary type is that much lower temperatures are usual, as the operator stands by the inlet to the machine and cannot stand the heat and steam. This makes it necessary to reduce the temperature. Exhaust fans should be fitted as standard to all can washers, as this would overcome the difficulty and make the operator's job much more bearable. The process with most washers is as follows: (*a*) Cold water rinse (*see* that there is enough pressure of water to hit the top of the inverted can). (*b*) Warm water rinse at 130° F. This is pumped under pressure and re-circulated. (*c*) Very hot detergent rinse also pumped under pressure. This should be as hot as possible, even up to boiling-point. (*d*) A hot jet of water from a steam and water mixer. (*e*) Live steam (Fig. MC 3). (*f*) A hot air blast to dry the can out. The lids usually go through beside the cans, and this is often a hit and miss method.

The tunnel type of washer is used chiefly in the larger dairies, where the output of clean churns is from 8 to 12 per min. (Figs. Cu 3 and 4). The drawback to this type of machine is that there is rather a fine limit in churn size which can be washed in any particular machine. If the creamery has a standard type of can then I would not hesitate to recommend the use of a tunnel machine. It must be remembered that no type of churn washer will wash cans which are coated with sour milk: these should be first washed by hand and then put on the machine. No creamery can hope to have a good milk supply unless it provides the farmers with dry sterile cans. No creamery can hope to get a good name for its milk unless the cans into which the milk is put after processing are clean and sterile. Do not be tempted to send loads of empties to farms as they come from your customers. See that they are washed again to avoid any possibility of trouble. In the tunnel machine the processes through which the churn passes are much the same as the rotary machine. Owing to the fact that higher temperatures are possible some operators dispense with the use of detergents: this is a considerable saving. Whatever churn washer you use must be properly supervised. If detergent is used the laboratory must take periodical samples to test the strength, and if below strength should advise the operator the correct amount of detergent to add to make it up to strength. The laboratory should record hourly the temperatures of the various rinses and the pump pressures. Just a word of warning here: always view with suspicion dial thermometers, particularly those with long capillary tubing. This type of instrument has been known to be as much as 50° F. out of truth. *See* Churns.

Milk Processing Plant. The materials in general use for making plant are stainless steel, tinned copper, and tinned gun-metal. I would strongly advise stainless steel, as it is far ahead of any other material. It is usually not affected by the chemicals used for cleaning, but brine will definitely eat it away in the presence of heat. For storage tanks glass enamel is quite good, but is more easily damaged than stainless steel. For pumping milk I prefer the centrifugal single blade impeller type of pump (Fig. Pu 1). The pump should be designed for the job it has to perform. There is little evidence of any ill effect on milk by pumping, but the less pumping the better. Every additional piece of equipment is a source of contamination and something extra to clean. All milk piping should be so erected that it can easily be taken down; short lengths of 6 ft. are easier to clean and handle than longer lengths. Cone joint unions are more hygienic than those using a rubber joint, but the latter are less likely to give trouble with leaks. Every dairy should be provided with one or more pipe sterilisers: these are usually galvanised iron cylinders about 10 ft. long and varying in diameter. Steaming pipes by blowing steam through them is a hit-and-miss method, and is never satisfactory. The pipes should be kept at a temperature of not less than 180° F. for at least 10 min. The question is often asked as to whether it is really necessary to take pipes down *every* day. In my view it is necessary, and to vary from the routine lowers the standard. I need hardly emphasise that it is useless sterilising pipes if they have not previously been washed inside and out with detergent solution. *See* Cleaning and sterilising.

Cooling Milk. This is a process carried out in almost every dairy. Cooling merely retards the growth of bacteria, it does not kill them and when favourable temperatures for growth are regained after cooling, deterioration of the milk will continue according to the temperature and the number and type of bacteria present. The usual temperatures to which milk is cooled are from 36° to 44° F. ; 38° to 40° is perhaps the commercial ideal. There are several types of cooler in general use :

(i) *The capillary type of open cooler with or without covers.* This type of cooling has gone out of fashion owing to the difficulty of thoroughly cleaning all the corregations. It is also difficult to sterilise properly. Do not forget that with all types of cooler you must be able to empty the water and brine out, otherwise these will stop the metal from becoming hot enough during sterilisation. Always remember the elementary fact that it is not the steam which sterilises, but the heat the steam carries.

(ii) *Plate type, enclosed type cooler.* This type is easily the most popular to-day. This is really like a filter press, the cooling plates with their dividing plates being compressed by means of a screw (Figs. P 5 and 10). To clean the cooler the screw is undone and the plates are then easily exposed for cleaning. The worst feature of this cooler is the rubber joints which do not last very long unless they are carefully treated. The cooler should not be *over* tightened at any time, otherwise the rubber will be compressed. A cooler of this type has a large capacity for the space it occupies. The cooling medium is usually water and then brine : water is sometimes dispensed with, but this adds additional load on the refrigerating plant. It is usual to use 2 gal. of water to every gal. of milk cooled, and care must be taken to prevent the cooler freezing up. The brine should be shut off a minute or so before the milk is stopped circulating.

(iii) *Tubular enclosed type cooler.* This is a good type of cooler and consists of a number of tubes in a larger tube through which the cooling medium circulates (Fig. Co 5). The milk circulates through the batteries of tubes in the opposite direction to the cooling medium : it is sometimes called a counter-cooler. A large capacity can be obtained in a small space. It is easy to clean and sterilise, but do not fit stainless steel tubes in the brine section, as the brine will eat holes in the tubes and cause brine leaks into the milk. *See* Cooling.

Pasteurising Plant. There are two types now licensed named the " Holder System " and the " High Temperature-Short Time System ". Some operators still have a liking for the Holder System (Figs. P 2*a* and 2*b*), contending that there is a greater margin of safety with this type. The writer has no hesitation, from experience of both types, in declaring himself fully in favour of the H.T.-S.T. System (Figs. P 4 to 19). In the Holder System there is much more plant to clean and sterilise, and the plant takes up more space. Another feature is that no milk comes *from* the plant for about 40 mins. after it has been started up, and this delays the bottling and the washing down of the plant at the end of the run. With the H.T.-S.T. plant pasteurised milk is coming from the plant within seconds of milk entering the plant. There is little, if any, difference in the keeping quality of the pasteurised milk. The modern flow diversion valve is a clever and reliable instrument. The operation of a modern H.T.-S.T. plant calls for no specially skilled attendant, but simply the use of common sense. If the plant is properly operated the temperature should not vary more than ½° F. throughout the run. The minimum temperature permitted is 161° F. During hot weather there is a tendency to put the temperature up to as high as 165° F. My experience is that there is no appreciable improvement in the keeping quality at the higher temperature and, furthermore, the cream line is ruined. *See* p. 793.

Refrigeration. This is one of the most important items of plant, and in designing a dairy always be generous in the refrigeration (Fig. Rf 2). The usual cooling medium is brine, but some dairies use chilled water or direct expansion ammonia. If using brine, make monthly tests of the brine to see that it is sufficiently alkaline, as acid conditions can cause the brine to become corrosive, with disastrous results to the iron piping and coils. I have seen cast iron so softened that it could be cut away in chunks with a pen knife. In designing a refrigerating plant always leave room in the compressor room for additional machinery. Also, make sure that the evaporator coil is large enough to cope with all the compressor capacity you have. Most dairies make the mistake of being short of evaporator capacity. The type of condenser to use is entirely dependent on the conditions and the space available : the makers of the plant will advise you on this. Keep your compressor room clean and tidy. If you can tile your walls and floors so much the better. Money spent on what appears to be unnecessary refinement is usually repaid in the long run. Do not make the mistake of running your brine at very low temperatures as it is uneconomical to do so ; 25° to 30° F. is an ideal temperature and there is not so much chance of freezing up as at lower temperatures. *See* Refrigeration.

Boilers. The successful manager decides what steam he will use and then doubles the answer, and puts up a boiler house which will hold twice as many boilers as he wants to start with. I have seen too many dairies equipped with totally inadequate boilers. Preferably have your boiler house away from the dairy. There are two reasons for this, firstly, cleanliness, and secondly, you may want to extend your dairy and will then find that your boiler house is in the way. You can always carry steam from the boilers to the dairy without much loss through insulated piping. The type of boiler to use depends entirely on the duty and the type of work to be done. Most small dairies can be satisfied with the vertical type of boiler, with horizontal smoke tubes. This type is fairly efficient and costs little to install and takes up the minimum of space. Two boilers, either of which will carry your load, should be installed. This will enable you to shut one boiler down for cleaning, repairs, etc. If your water is hard it will pay you to soften it by the use of a softening plant or special preparations known as boiler fluid. A boiler that is coated with lime loses efficiency, and will cause trouble by excessive local heat on the tubes and fire box. In the medium-sized dairy I think the " Economic " type of boiler is best (Fig. MC 4). It is quick steaming and is easily fixed. One must remember that in most dairies, particularly manufacturing ones, the load is extremely variable, and this puts a great strain on a boiler. Some engineers will advise you to install super-efficient double return boilers, but I would strongly advise against this, as they will not stand the variable load. The larger dairies cannot do better than install Lancashire boilers (Fig. MC 5). These are very expensive to install, but are wonderfully reliable and have a very long life. They will stand the strain of an up-and-down load much better than the other types of boiler. The question as to whether to fit mechanical stokers is sometimes a difficult one to decide. In the main, I would say that all boilers are better fitted with them, as a certain economy is effected in the use of fuel. The opening and shutting of the fire door for hand firing wastes a lot of heat. I should say that all Lancashire boilers should be fitted with an economiser to heat the boiler feed water with the waste heat from the flues. A brick chimney is preferable to a metal one, although the capital expenditure is higher. Always build a chimney high enough, and with enough internal area to meet any calls on it. It is cheaper to have natural draught than to have forced or induced draught. You should make sure that all the *clean* hot water in your dairy is directed back to your boiler feed tank. Remember that your boiler feed pump will not *suck* hot water, so put your boiler feed pumps below the level of your feed tank. I would like to emphasise the need for tidiness in the boiler house. A clean and tidy boiler house is usually reflected throughout the dairy.

Water Supply. No dairy should be built unless a plentiful supply of water is assured. If possible try to get several sources of supply. The quantity of water used depends on the type of process to be carried on. An ordinary liquid dairy would use 3 gal. of water for every gal. of milk processed, and 1 gal. of this 3 will become soiled and will require treatment unless there is a convenient sewage scheme. Thus, a dairy handling 10,000 gal. of milk daily will require 30,000 gal. of clean cold water daily, and if not connected to a sewage scheme an effluent plant to handle 10,000 gal. daily. River water is quite useful for cooling purposes in the winter, but invariably rises in temperature in the summer to such an extent as to make it useless. It cannot be used for washing down purposes as it is usually polluted. For condensing purposes river water is invaluable, as the quantity used makes it out of the reach of most boreholes. An ordinary condensing plant uses 20 gal. of water to every gal. of milk condensed. The warmer the water the more you use, and vice versa. It is possible to cool water and re-use it, but if possible avoid this by having an adequate supply. Never build a condensery where you are not assured of a limitless supply of water, and just as important is the means of disposal of the used and slightly contaminated water. The ideal water supply is a combination of a river, borehole, and towns main. The river water can be used for cooling condensers, and the borehole for milk coolers and general washing down, and the town main as a standby to the borehole. If the river water is very sedimentary it may be more trouble than it is worth, and it will then be wise to use borehole or town's water and recirculate. Periodic laboratory testing of the clean water supply should be done, and if necessary the water chlorinated. A dairy cannot afford to use polluted water. *See* Water Supplies.

Cold Storage. Every creamery, except the ones which sell all their milk in road or rail tanks, should have a cold store. Be generous in its size, as they are difficult to increase in size. If one wants to err on the large side, build a cold store with a partition so that one side can be left unused until needed. The usual construction is 4 in. of slab cork in two 2 in. layers. The floor, ceiling, and walls are all insulated. The average dairy will not want a store colder than 38° F. The floor should " fall " to the doors, and there should be no drain in the floor. The walls should be finished in some smooth material to facilitate cleaning. It is advisable, if not necessary, to finish the walls with sheet metal to prevent damage by churns, crates, and trolleys. This is very important at the doorways, where the corners will soon be damaged unless protected. The floor finish is important, and the best finish I know is cast iron grids 12 in. sq. set in concrete or asphalt (Fig. MC 6).

Creamery Transport. This perhaps is one of the most important matters which the creamery manager will have to handle. I will only deal with this briefly and strictly from the management angle. Unless the milk comes into the dairy in good time the working of the dairy will be unduly protracted, and the milk will have deteriorated in quality. Milk should all be in the creamery by 3 p.m. or before, if possible. The ideal is for a creamery to be surrounded by its supply on all sides. Rationalisation of farms is another big factor in economy of running transport. The ideal is for one firm's lorry to collect every farm it passes on its route, and not to be weaving in and out of farms selling to other buyers. Regular and reliable transport keeping good time daily is a big factor in good relationship with producers. If a lorry calls for a farmer's milk at the stand a mile away from the farm at mid-day one day and at 9 a.m. the following day, it is inevitable that the lorry driver will have to wait for the milk or go without it. The latter is unfair to the farmer, and will lead to complaints. The driver collecting milk can be an excellent ambassador, or the reverse. He should be impressed with the old idiom that " civility costs nothing ". Serious consideration should be given to the type of vehicle and also the type of body. To buy vehicles with standard drop-side bodies is, generally speaking, not making the best of things.

It is the writer's view that the Diesel-engined vehicle of some degree of quality is more economical than the cheaper mass-produced job. The repairs and maintenance costs are lower, and the cost of fuel is less, but to offset these factors is the higher initial cost. With vehicles on 7 day collection a thorough and systematic maintenance scheme must be introduced. As far as the drivers are concerned a 6 day week is highly desirable, and should, where possible, be introduced. The question of churns is of great importance. It is wise to standardise on one sort and size of can. The best, in my view, is the 10 gal. can with the 13 in. diameter base. On a body 17 ft. 6 in. × 7 ft. 6 in., 100 of these cans can be carried. With collection it is not so much a lorry's ability to carry weight, as the churn capacity which counts. So many cans are part filled that without a big body the gallonage carried is small, and the return unremunerative. The *delivery* of milk by road has made great strides in recent years, and for large quantities there is nothing to beat the 3000 gal. tanker mounted on an eight-wheeler chassis. In the event of a 3000 gal. tanker being too big for the amount of milk to be carried, the 1500 gal. job is very good, and perhaps better in some ways than the very large one. If the 3000 gal. tanker breaks down or gets ditched, it is rather a problem to overcome. Two small tankers can help one another out in the event of trouble. The articulated chassis has good points, but has not got the road grip which the normal drive machine has, and in frosty weather the articulated vehicle will be standing whilst other vehicles can travel. The best material for road tanks is stainless steel; aluminium is lighter but is less durable (Fig. Tr 1). Remember that the more weight in the tank the less weight of milk will be carried.

Rail tanks are constructed in a similar manner to road tanks, but the question of weight is not so important (Fig. Tr 2). The writer's view is that bulk road transport, up to 150 miles, is quite satisfactory, but distances above this figure are better done by rail tanks, if possible. For a creamery which is not rail connected there is the road-rail tanker method. This is usually a 2000 gal. tank mounted on a trailer chassis, and this trailer with the tank mounted on it is run on to a railway chassis by a ramp and fastened by chains. The disadvantage is the time taken loading and unloading, and the necessity for a towing lorry or tractor to be always available: this method of transport should be avoided if possible. On the question of bulk transport I would emphasise the need for very thorough and prolonged plunging of the milk, otherwise the first milk out of the tank will be very low in fat, and the last milk out very high. If, of course, the milk is being pumped into another bulk tank in the dairy, and this tank is not being drawn on until the rail or road tank is empty, the above precautions are unnecessary. Milk carried in bulk tanks can be safely transported hundreds of miles if in good condition when cooled. The temperature should be not more than 38° F. and even in the hottest weather the temperature at the receiving end the following morning will not be above 42° F. I would always advise insulated tanks, except for short local journeys. There are two common methods of emptying bulk tanks—pumping and blowing out with compressed air: both are satisfactory. The tanks should be fitted with an air pressure release valve, in which should be incorporated a vacuum release. More than one good vessel has been ruined by steaming the tank and then closing it up. When it cools off a vacuum is caused which, unless a release valve is fitted and *works*, causes the sides of the tank to collapse.

The cleaning of bulk tanks is not difficult if approached in a conscientious way. The receiving end should have given the tank a wash out with warm water to remove any milk, and when received back at the creamery the tank should be thoroughly washed again. The usual method is to put some hot detergent solution in the tank and the cleaner to get in the tank and scrub it down thoroughly with a long-handled brush. See that your tank washer is provided with rubber thigh boots and oilskin overalls. On no account let him get in with boots or clogs on, as he will probably injure himself and the lining of the tank. After the hot soda wash the tank is hosed out with hot water. The fittings are then taken off and cleaned separately. Most of the contamination in a tank is found in dirty fittings which have not been taken off for cleaning. After the fittings have been replaced the tank is then sprayed or rinsed with hypochlorite solution, or steamed. Steaming is perhaps the most efficient way, but is rarely practical An insulated tank will need at least an hour's steaming, and will require 12 hr. to cool off thoroughly before being filled again. This is rarely practical, and the chlorination method is the most practical. Experiments have proved that not much contamination takes place from bulk tanks. I would strongly advise, however, that the same standard of cleanliness should be adopted as with the general cleaning in the dairy. Milk is easily the most perishable of articles to transport, and breakdowns are usually expensive; therefore, maintain your fleet in the best possible way. Tyres should be carefully kept up to pressure, and a spare always carried. A good mechanic who can see trouble before it arises is a valuable asset. Remember that your vehicles are the part of your business which is most in the public eye, and therefore see that they are well painted and kept clean. The organisation of your transport is a matter which is well worth your attention, as so much of your expenses are involved in transport. In most liquid depots half or more of the total wages are paid out for transport. A badly organised transport section has a most harmful effect on the running of the dairy. The organisation of "collection runs" is a matter to which the manager should give his close and *frequent* attention. The first step to take is to map out the position of each farm on a "1 in. to the mile" ordnance map: small pins with coloured heads are very useful for this. After having mapped out each collection route in different coloured pins it is easy to see where overlapping is taking place. An ideal collection is one which has flexibility to meet the ups and downs of production. It is not good enough to run your lorries half loaded when the milk is low, to leave room for the flush. The lorries should be so run that at the lowest production they are fully loaded with cans of milk. I stress *cans* of milk because it is not possible to carry full gallonage at the low production. It is wise to review at least monthly each round, and where possible merge or split up rounds. The closest attention to these matters will reveal itself in the transport profit and loss account. If possible each vehicle should collect not less than a 1000 gal. per day on an average. This will involve two journeys, and the second journey should be in the creamery yard before 3 p.m., as later collection than this will cause complaints from farmers and the National Agricultural Advisory Service. A good manager must be just as good a transport manager as he is a dairyman. *See* Transport.

Wastage. This is a problem which confronts every creamery manager daily. I have often been asked what wastage a creamery should incur, and the answer is that it depends entirely on a chain of circumstances. I suggest that the following would be somewhere in the region of reasonable figures: a creamery getting all its intake direct from producers and brine cooling only into tanks, 0·3 per cent.; a creamery getting all its milk direct from farmers and sending it out all in churns, 0·4 per cent.; a creamery getting all its milk direct from farmers and sending it out all in bottles, 0·6 per cent. The difference in wastage incurred in pasteurising, as against brine cooling, is so slight as to be negligible.

Whether you weigh your milk in, or check by a government stamped measure, the greatest keenness is necessary. On an intake of 20,000 gal., if each can received averages a pint short, there will be a leakage of 275 gal. daily, and this added to spillage and possibly over-measure on the outward milk, will mean very high figures. Whatever else you do always carefully record your stock each night, and work out your wastage as soon as possible afterwards. Never be tempted to put down an estimated wastage figure. Always put down on your books the actual figure for the day, however unpleasant it may be. I have, on a number of occasions, been called in to correct an excessive wastage, and this can be done in stages as follows: first incoming milk, second outgoing, third leaky pipes, pump glands, and general carelessness, and fourth pilfering. I have known wastage as high as 6 per cent.; this particular case was due to roundsmen having access to the cold store and no check being kept on what they took on their rounds. When each man signed for what he took and had to account for it, the wastage dropped in a night to under 1 per cent., and several roundsmen found themselves in the police courts. Always encourage your drivers to report spillages, and do not reprimand them unless they are persistently careless. If they are penalised for spillage they will not report them, and you will find yourself faced with unpleasant claims from producers. On large milk storage tanks it is wise to have in addition to a valve, a blank cap, to ensure that if the tap is opened by accident the contents of the tank do not run to waste. The question of wastage has a very big bearing on your profits. Even a well run dairy handling 10,000 gal. per day will lose up to £2000 per annum, and a badly run one can easily lose double this, or more. You can easily justify your salary by this point alone.

Handling of Churns in a Creamery. I have rather strong views on this, which may be useful. I do not believe in a large expanse of loading dock on to which drivers will unload their milk. I consider this is wasteful of time and labour. I consider that the dairy should be capable of handling the loads of milk as fast as they come in. The method I like is that where the driver unloads his full churns on to a conveyor, either roller or power driven, and the milk is checked on the conveyor and tipped from it. By this method all rolling of cans is avoided, and it is possible to keep perfect order and flow throughout the day. There must be no bottlenecks. You must have a churn washer capable of washing the cans as fast as the driver can unload. A dairy handling 20,000 gal. per day should be capable of receiving a steady 11 cans per min. with two lorries unloading, two checkers, two tippers, and two men on churn washing. Another advantage of the conveyor system is that it does away with floor wear almost entirely. A suitable " stop " device should be fitted to the conveyor, so that the checker has time to examine the churns properly without their being on the move the whole time. Lay your plant out in such a manner that the churns, after being tipped, have adequate time for drainage. It is surprising how much milk is left in a churn even after it has been carefully tipped, and I would advise the drainage of cans up to ½ min. This is usually the maximum time possible under commercial conditions. Even after this period there is still quite an appreciable quantity left in the can. The drainings usually contain rather a high percentage of dirt solids which should be carefully strained. Do not store up your drainings throughout the day, but put them in the bulk at *frequent* intervals. A day's tipping, say 3000 churns, will get about 30 gal. of drainings daily, and although this milk is of rather doubtful cleanliness it would be a big loss to throw away or feed to pigs.

Cheesemaking. I can only deal with this subject in general terms. (*See* pp. 168 to 219 for more detailed treatment.) Cheesemaking is, in my view, quite the most difficult of any of the dairy processes. No man should adopt cheesemaking unless he is prepared to give himself up to it heart and soul. His reward for the long hours and hard work he puts in during the season will be amply repaid by the pride he can justly feel by turning out a good article. Good cheese are not made by chance. Cheesemaking is a planned operation, and the degree of success depends on each and every detail being perfectly carried out.

The question of whether to pasteurise milk for cheesemaking is one which has not been entirely decided. I would say that in a large factory with milk from different areas, or even counties, it would be much wiser to pasteurise, as one starts with a cleaner milk free from coli, and consequently a milk which is less likely to " play tricks ". For a small dairy with a good cheesemaker who has time to give individual attention to each vat, I think that good cheese can be made without pasteurisation of the raw milk. A good cheesemaker is always careful about his starter. I would advise that starter be kept as far away as possible from the cheese room to avoid contamination. I have heard it said that the storage of cheese is even more important than the making of it, but I would hardly go as far as that, although it does call for the most particular attention to detail. Cheesemaking usually takes place in the summer months of May, June, and July, and sometimes April, August, and September. All these months are hot months, and cheese stored in hot rooms are liable to deteriorate. I would strongly advocate that cheese from the age of 14 days should be stored in rooms which are air-conditioned. Very low temperatures are not necessary or desirable—55° F. is a sound moderate temperature at which to ripen cheese. The appearance and finish of cheese are a great selling asset: a buyer would always pay a better price for well-finished, straight, level cheese, than crooked cheese with rounded edges. A good cheesemaker's pride will not permit him to make shoddy-looking cheese, even if the cheese itself is alright. An excessively damp atmosphere will encourage mould formation, and this is not desirable. On the other hand, precautions should be taken against draughts, which will cause cracking of the coat of the cheese. Good ventilation without direct draught is what is required. Cheese should be turned daily up to a month old, and then at regular intervals.

Blue-veined cheese. The chief varieties of these are Stilton, Wensleydale, and Gorgonzola. These cheese are a specialised business, and should not be attempted without giving very full consideration to the whole subject. Generally speaking, large quantities of milk cannot be manufactured into blue-veined cheese owing to the large amount of equipment needed, and the amount of personal attention required to every detail. Even in the best-run dairies, a large percentage of the cheese do not turn out true to type, and have to be sold at lower prices. If, however, a good product can be made and a good high class market found, it is a highly profitable business. The general public have the impression that the mould is put in the cheese by insertion of wires or skewers, but if the cheese is properly made no artificial means of inserting mould growth is necessary. The growth of mould depends on how the curd is put together, and the air space between the individual pieces of curd. No blue-veined cheese is pressed, as this would exclude the air which is necessary for mould growth. Good air-conditioned storage is absolutely necessary for the making of blue-veined cheese.

Whey. This is a by-product of cheesemaking. The composition of it is as follows:

	%
Water	93·40
Fat	0·35
Casein	0·10
Albumin	0·75
Milk sugar	4·80
Ash	0·60
	100·00

There are a number of ways of disposing of the whey, and these are as follows:

(i) It can be fed to the pigs, but the difficulty here is storage of the whey until it can be consumed, and the uncertainty of how long cheesemaking will be permitted, as if the cheesemaking finishes before the pigs are ready for the market, and they have to be fed on water and meal, they will lose condition. Whey is a very foul liquid when it goes sour, and must, at all costs, be kept out of rivers or effluent plants. It will soon seriously pollute the river and kill plant life, with bad results on the fish. I know of no effluent plant which will handle whey, except in very dilute solutions. If whey is fed to pigs the piggery should be kept far enough away from the dairy so that there is no smell. It should be borne in mind that the effluent from a piggery is almost as bad as raw whey, so that special precautions should be taken to see that all strong liquid from the piggery is not put through an effluent plant, or into a river, but pumped on to the land where its manurial value will be beneficial. *See* Pigs.

(ii) The whey can be dried or condensed. If the latter, the resultant product is generally used for the production of lactose. Drying whey is usually done on rollers, and the product comes off the rollers in hard cobs, not in sheet form as does milk. This is because of the higher milk-sugar content. For the same reason the product is darker in colour than dried milk. The sugar becomes partly caramelised due to the high temperatures of drying. After manufacture the dried whey cobs are usually ground to a fine powder in a mill, and in this form it is a valuable foodstuff. It is usually sold for cattle food in bags, but the price is rather low usually, and owing to the low total solids content (6·6 per cent.) the cost of drying is high. It is, however, a means of getting rid of whey without pollution, which is the biggest problem for the cheesemaker. *See* Whey.

Butter. This dairy product is perhaps the most widely used of any product, and its manufacture dates back for centuries. In olden days the receptacles used for buttermaking were, of course, primitive, and varied from the skins of animals to tree trunks hollowed out and swung from a beam above. The same principles apply to-day, but the advent of the centrifugal separator has revolutionised buttermaking. (*See* p. 132 for more detailed treatment.)

Separating. The milk is whirled round in the bowl and the heaviest portion is swung out and the lightest—the cream—up the centre cream tube. Separators have, during the last few years, made great strides, and the modern " foamless " machine, with direct drive through a centrifugal clutch, is a highly efficient machine. If properly run, the amount of froth on the separated milk is greatly reduced as against the ordinary type of machine. Separators vary in size from 50 gal. to 1300 gal. per hr., and the larger sizes are invariably made abroad. A separator does not require highly skilled attention, but do put a man with common sense on the job. A man who will take a pride in his machine will prove an asset to you. The putting together of the machine should be in the hands of one man, and not just anybody's job. If you had seen a separator come to pieces at a speed of 6000 r.p.m. you would appreciate my point. If the separator shows any signs of peculiar behaviour, such as unusual vibration, stop it at once and find out what the trouble is ; maybe your engineer in his zeal has tightened the frame down on to the bedplate so tight that the rubber cushions are squeezed down tight and have lost their flexibility. This will cause the most dreadful and dangerous vibrations. Always use the proper grade of oil, and change it about every 100 hr. running : this will improve the life of your machine. Always carry a good stock of spares, especially rubber washers and joints. The best temperature at which to separate your milk is 100° F. Below 70° F. there is an appreciable increase in the amount of fat left in the skim milk. The modern separator will run for 3 hr. before it requires taking down for cleaning, and there will, by this time, be about ½ in. thickness of " skin " in the bowl, which must be removed. The cream is the valuable part of the milk, but the skim is a valuable product which can be dried, condensed or made into casein. As soon as possible after separation the cream must be pasteurised. There are three methods in general use, and I hesitate to say which is best, as they are all effective and have certain advantages over the other. There is the flash method whereby the cream is heated to 180° F. or above and immediately cooled : there is the batch system where the cream is heated in holding tanks to 145° to 160° F. and held for about 30 min. : and there is also the method combining continuous flash and holder. The first-named method reduces the amount of cleaning and waste, but the latter two methods ensure a more positive heating. It is essential that the cream for buttermaking should have a very low bacterial count. It is very desirable to fit a vacuum deodoriser to take away any possible smells which would have an effect on the butter. Up to recent years it was the general practice to ripen cream for buttermaking with a good starter, but of recent years the fashion has turned round to the churning of unripened, well-pasteurised cream. In fact, the Ministry of Food stipulate that cream should be churned fresh and unripened.

Churning. There are a number of different types of churns on the market, and perhaps the most popular is the *combined churn and butter worker.* It is certainly labour saving, but some claim that it is difficult to clean owing to the worker rollers, and that by having a separate worker the butter can be taken out of the churn more quickly and the next churning commenced. My opinion is that it is a matter of choice : very excellent butter can be made by either method. The transfer of the cream from the holding tanks to the churn is a matter of some importance. It is not desirable to pump the cream, so if possible arrange your plant to get gravity flow from the storage vessel to the churn. In laying out your plant ensure that you have an adequate supply of cold water : it is usual to have a small cooling plant with brine for this. Do not overload your churn with cream, ⅓ to ½ full is enough, and if you put more than this in you will lose time as you will not get the necessary agitation. Better results are obtained by churning cream with about 33 per cent. butter fat content. The temperature of churning is also important—46° to 48° F. in summer and 54° to 56° F. in winter. Sweet cream takes longer to churn than ripened cream. There is a rise in temperature during churning, and the difference between the starting and finishing temperatures is about 3° F. Great care should be taken to see that cream does not come in contact with metals which will cause taints in it. I would strongly recommend the use of all stainless steel for anything which comes in contact with the cream, as there is nothing like cream for taking up taints. The pumps used for pumping cream are invariably positive type rotary pumps, and the rotors and bodies should be made of stainless steel. I like the cog type of rotary pump, as it is easily cleaned and wears well (Fig. Pu 2). A plentiful supply of clean pure water is one of the first essentials for a butter factory. The main skilled operation in buttermaking is to stop churning at the crucial moment. No amount of book reading will give this skill to you : it is only by working with a skilled man that you will get this experience. Overchurning will result in a large grain and a consequent incorporation of buttermilk with bad effect on the keeping quality of the butter. When the cream has " broken " on the sight glass the " breaking water " should be added, and the churn started up again until the grains are the size of large wheat grains. The buttermilk should then be run off and the butter in grain should be washed. The amount of washing depends on the quality of the cream. The purpose of the washing is to remove all traces of buttermilk; if these traces were not removed the butter would be of poor keeping quality. The temperature of the wash water should vary with the time of year, the atmospheric temperature and the firmness, or otherwise of the granules of butter. The salting of the butter depends on the public taste, and the amount of salt may vary from 0·5 per cent. to 2 per cent. Only a high quality salt should be used. A useful method of calculating the salt to be added is as follows:

Example:

850 lb. of fat are in the churn. Butter is to contain 2 per cent. salt.

Answer:

$$\text{Lb. of salt per 100 lb. fat } 2{\cdot}0 \times 1{\cdot}25 = 2{\cdot}5 \text{ lb. salt.}$$

$$\text{Lb. of salt to add to churn } \frac{2{\cdot}5 \times 850}{100} = 21{\cdot}25 \text{ lb. salt.}$$

There are two usual methods of adding the salt—dry salting and wet salting. The dry method is the most common and perhaps the most satisfactory.

Working the Butter. The purpose of working the butter is to bring the butter granules into a compact mass. This is done either in the churn or by the transference of the butter to a separate worker. The amount of working must be left to the skill of the buttermaker. The final product must not contain more than 16 per cent. moisture—this is the legal maximum. It is obviously foolish to overwork, and thus reduce the moisture unduly, as this will result in reduced yield.

Cold Storage of Butter. The production of butter is usually of a sporadic nature, and in the flush months the production is very high and tails off towards autumn, and stops altogether in the winter. To cope with the problem of storing the peak production, cold storage is necessary, and the temperature will depend on the length of time the butter is to be stored. Low temperatures of about 10° F. are quite usual.

Legal Obligations which a Creamery Manager should be Aware of and Carry Out. The legal minimum fat percentage is 3 per cent., and the legal minimum of non-fatty-solids is 8·5 per cent. A Sampling Authority is entitled to take samples in the course of delivery, or awaiting delivery : it is unwise and illegal to hamper an official in the execution of his duty. My advice to you is to give Sampling Authorities every assistance. If you are an honest trader you have nothing to fear. If you have farmers who are sending you in milk persistently watered or skimmed, call in your Local Inspector : he will appreciate this, and he will soon put a stop to these malpractices.

You will be working under the Factory Act, and must comply with all its regulations. They are too numerous for me to enumerate here, but for a few pence you can buy from H.M. Stationery Office the pamphlet dealing with it in detail. If you are ever in doubt ask the Factory Inspector to call and see you, as invariably these gentlemen (or ladies) are most helpful, and although they have large powers they are very reasonable. The main concern is that work-people should have safeguards for their health and limb ; dangerous machinery such as shafting, couplings, etc., should be securely fenced. By the way, fencing in itself is not enough : the fencing should be *used*. I have often seen it put on one side.

Machinery should not be greased when in motion, especially by juniors.

The requisite notices should be exhibited, and I would advise you to paste them on a board, and then varnish them to keep out the damp.

Make sure that your factory register is kept up to date, and that boiler reports are to hand for the Inspector to see. If the Inspector serves notice on you to carry out certain improvements for the employees' safety or welfare, do not argue that it is unnecessary, but get it done promptly and with a good grace.

The Milk Distributive Trade Board notices should be posted, and proper records kept. An Inspector of the Trade Board has a right to inspect all your books dealing with wages paid.

Milk Marketing Board auditors have a right to inspect certain books dealing with milk received, dispatched, rebates and carriages claimed.

Your local Medical Officer of Health and Sanitary Inspector have the right to inspect your plant and premises. Receive them well, and if you have nothing to fear, the visits and advice should be appreciated.

Your steam boilers and other pressure vessels have to be inspected by a qualified engineer from an approved insurance company. Most of these engineers are very competent and helpful. *See* Agriculture ; Butter ; Cheese ; Condensed and evaporated milk ; Cooling ; Costings ; Dairies, design of ; Electrical equipment ; Farm advisory work ; Management of pasteurising depots ; Mechanical handling ; Milk marketing ; Milk powder ; Pasteurisation ; Pigs ; Quality payment ; Refrigeration ; Steam raising ; Whey.

MANAGEMENT OF DAIRY CATTLE. The general aim of the dairyman is to maintain in his herd the highest possible standard of health and productivity. Efficient management of dairy cattle depends on a good general knowledge of the normal responses of cows to different systems of treatment and a clear understanding of the capabilities and temperament of individual animals. Dairy cows are essentially creatures of habit and their treatment should be quiet and consistent at all times. Frequent handling from calfhood onwards helps to develop a quiet, responsive cow.

Adequate records are essential for efficient management. These include (*a*) Milk records which show the milk yield of every cow and provide a basis for rationing, for breeding, and for identifying the poor-yielding or unprofitable cows. Herd owners in England and Wales who join the National Milk Records Association, are helped with milk recording, provided with the necessary stationery and have their milk records certified as accurate. The Scottish Milk Records Association performs similar duties in Scotland.

(*b*) Records of service and calving dates are needed to ensure that the distribution of calvings throughout the year is in keeping with the requirements for milk. Thus, dairy herds which supply the liquid milk market need a large proportion of autumn calving cows in order to produce adequate milk in winter, but herd owners who supply milk for the manufacture of milk products usually arrange for most of the cows to calve in the spring and produce milk cheaply in summertime from grass.

(*c*) Records of breeding are essential in pedigree and " grading up " herds. These are kept in conjunction with the appropriate Breed Society.

Dairy Herd Replacements. The average productive life of a dairy cow in Great Britain is 4 to 5 years which means that more than 20 per cent. of the herd must be replaced each year. Some herds are replenished entirely from home-bred animals. This system enables the owner to maintain control over the breeding of his cattle and avoids the danger of introducing disease into the herd through purchased animals. Other herds are replenished by purchasing newly calved cows. These are called " flying herds " and the system permits the herd owner to keep more cows in milk than would be possible if young dairy cattle were reared on the same farm.

Housing of Dairy Cattle. The climate of Great Britain is sufficiently rigorous to make it desirable to house dairy cattle in winter time. The exceptions to this practice are a small proportion of dry, well-drained farms which have some natural shelter.

Calves under 6 months of age are almost invariably housed and they thrive best when provided with a deep bed of straw and are protected from ground draughts. When cattle reach about 18 months of age they are usually left out of doors at all seasons of the year until the first calf is produced.

Milking cows on most farms graze pastures by day and night in summer but are housed by night in winter. A small proportion of dairy herds are not housed even in winter ; these are sometimes milked in the fields by means of a portable or " bail " type of milking machine.

Bulls are almost always housed in order to keep them under control rather than to protect them from weather conditions.

The system of milking and its efficiency exercises a marked effect on the milk yields. Thus, cows are usually milked twice during the 24 hr. but more milk is yielded if they are milked more frequently. The general effect on milk yield of the interval between milkings is illustrated in Table MDC I based on the work of Brody and his collaborators (*see* Brody, *Bioenergetics and Growth*, Reinhold Pub. Corp., New York, 1945, p. 809).

Machine milking is gradually replacing hand milking in Great Britain because it reduces the amount of labour, particularly in large herds. A system of milking which has been widely publicised in recent years is the so-called " quick-milking technique ". The main features of this system involve (*a*) washing the cow's udder with warm water immediately before the act of milking is started in order to set in motion the reflexes which induce the " let-down " of milk (*see* Milk secretion). (*b*) When milking has started the milk is drawn as rapidly as possible because the effect of the hormone which is said to induce " let-down " is transitory.

(*c*) The milking machine teat cups are removed immediately milking is finished in order to prevent the teat cups creeping up the teats and causing damage to the udder tissue. (*d*) Machine-milked cows are not stripped by hand but the last milk is obtained by manipulating the udder and the machine. In many respects this system agrees with established practice, thus drawing milk rapidly has frequently been shown to benefit milk yields. Further, the adoption of the system necessitates a consistent and standardised routine in the cowshed at milking time which is highly desirable. There is little evidence, however, that the details of the "quick-milking technique" provide the only or even the most satisfactory routine for all dairy herds. The recommendation to avoid hand stripping is perhaps the most revolutionary feature of the system. There is little doubt that hand stripping provides the milker with an opportunity to observe clinical mastitis, and therefore when cows are stripped with the machine it is necessary to observe mastitis or udder abnormality from the first few streams of milk drawn from each teat by hand. The thoroughness of stripping probably depends more upon the skill and the alertness of the milker than upon the fact of whether he uses his hands or the machine.

TABLE MDC I

Intervals between milkings (hr.)	*Milk secreted in one interval (lb.)*	*Calculated yield in 24 hr. (lb.)*	24 *hr. yield expressed as a percentage*
6	5·0	20·0	116
8	6·3	18·9	110
10	7·5	18·0	105
12	8·6	17·2	100
14	9·6	16·5	96
16	10·6	15·9	92

Ref.: Petersen.

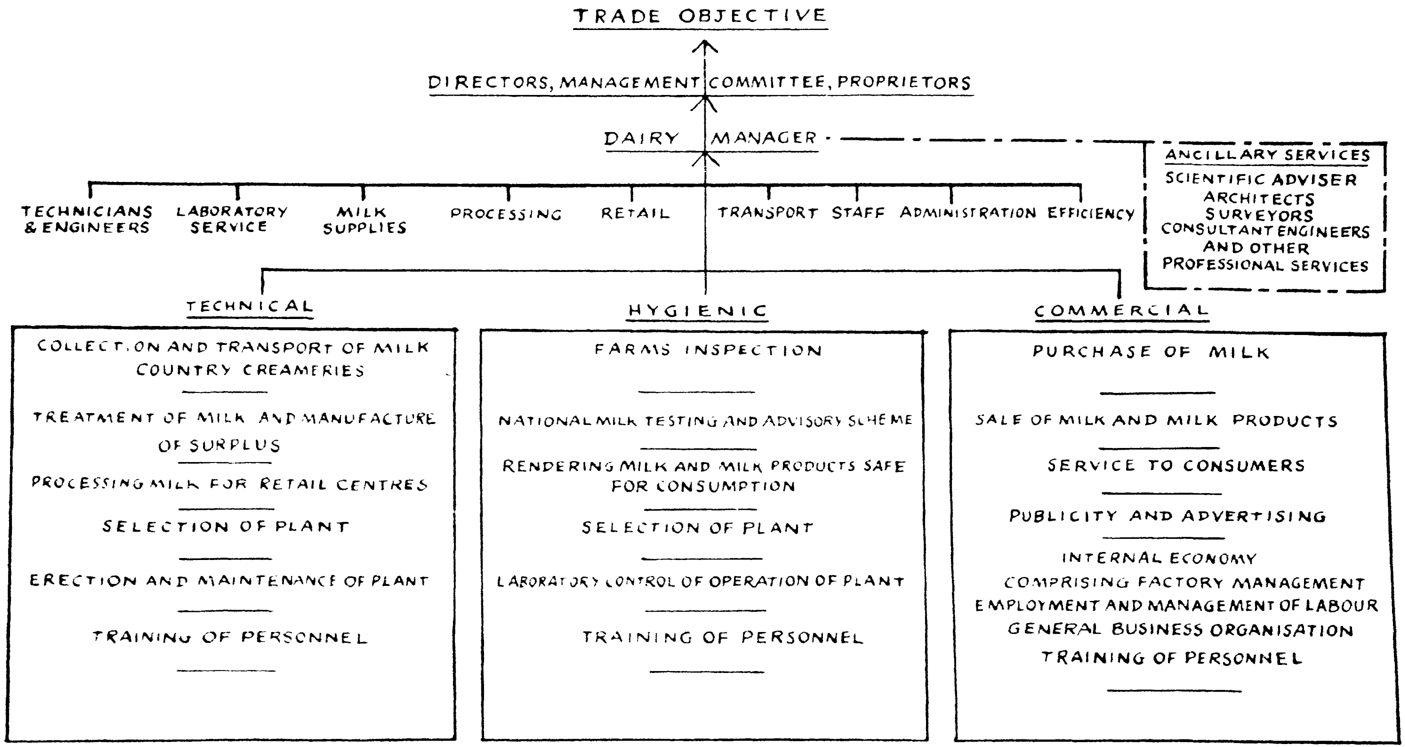
See Agriculture; Breeding; Costings of milk production; Feeding; Milk secretion; Milking machines.

MANAGEMENT OF PASTEURISING AND BOTTLING DAIRIES. The management, or manner of directing the activities of a business can be carried out by different methods depending on the size, nature, and scope of the undertaking. According to whether the business is one of the large companies, a Co-operative Society, or a privately owned firm, the dairy manager will be directly responsible to a board of directors, a management committee, or the proprietor. In each case, the formulation of the trade objective, the laying down of policy to be followed in attaining that objective, and the ultimate responsibility for the success or otherwise of the business must be the main concern of these highest levels in the undertaking's organisation.

The dairy manager, besides being the executive for interpreting and carrying out the policies so laid down, acts in the capacity of an expert adviser to his directors, committee, or proprietors in their deliberations. The purposes of this article will be well met and the discourse conveniently facilitated, if we assume that the management of a pasteurising and bottling dairy is vested in one person, namely, the dairy manager.

It is, therefore, by a review of the activities of such an executive that the principles of management will be elaborated.

For the sake of clarity and to establish at the outset the full scope of a dairy manager's functions, the organisation of a large scale commercial dairy, embracing all aspects of the dairy industry is set out diagrammatically in Fig. MPD 1.


TRADE OBJECTIVE
DIRECTORS, MANAGEMENT COMMITTEE, PROPRIETORS
DAIRY MANAGER
ANCILLARY SERVICES
SCIENTIFIC ADVISER
ARCHITECTS
SURVEYORS
CONSULTANT ENGINEERS
AND OTHER
PROFESSIONAL SERVICES
TECHNICIANS & ENGINEERS
LABORATORY SERVICE
MILK SUPPLIES
PROCESSING
RETAIL
TRANSPORT
STAFF
ADMINISTRATION
EFFICIENCY
TECHNICAL
COLLECTION AND TRANSPORT OF MILK COUNTRY CREAMERIES
TREATMENT OF MILK AND MANUFACTURE OF SURPLUS
PROCESSING MILK FOR RETAIL CENTRES
SELECTION OF PLANT
ERECTION AND MAINTENANCE OF PLANT
TRAINING OF PERSONNEL
HYGIENIC
FARMS INSPECTION
NATIONAL MILK TESTING AND ADVISORY SCHEME
RENDERING MILK AND MILK PRODUCTS SAFE FOR CONSUMPTION
SELECTION OF PLANT
LABORATORY CONTROL OF OPERATION OF PLANT
TRAINING OF PERSONNEL
COMMERCIAL
PURCHASE OF MILK
SALE OF MILK AND MILK PRODUCTS
SERVICE TO CONSUMERS
PUBLICITY AND ADVERTISING
INTERNAL ECONOMY
COMPRISING FACTORY MANAGEMENT
EMPLOYMENT AND MANAGEMENT OF LABOUR
GENERAL BUSINESS ORGANISATION
TRAINING OF PERSONNEL

ORGANISATION OF A LARGE SCALE COMMERCIAL DAIRY

FIG. MPD 1.

This figure shows the organisation behind the dairy manager, giving the nine main sections or departments by which the work to be done (divided broadly into technical, hygienic, and commercial) is accomplished. It should be realised that while on the whole each of the nine departments has its own specific tasks, in many cases their work overlaps or is interconnected. For example, staff (including staff welfare), transport, and administration (*i.e.* office organisation, wages, records, etc.) are intimately connected with the majority of departments, if not all. The same applies to the efficiency department, whose concern it is to apply time and motion study, and the principles of industrial psychology, etc., to each department in turn and the organisation as a whole. This shows the paramount need for team work in the organisation to make it act as a unit and be dynamic in the right direction, that is, forwards to the trade objective. Otherwise the movement will be backwards, for it is unlikely that a business can remain static indefinitely.

Fig. MPD 1 also shows that the dairy manager in his function of co-ordinator and expert adviser must, for certain aspects of the work, have resort to the ancillary services as shown. For example, the scientific adviser can furnish evidence of all research work which has been done on a particular subject, and thus the experience and findings of others can readily be made available and possibly utilised, which, of course, is the main object of research.

Again, while diagram Fig. MPD 1 has shown for simplicity's sake the work to be performed grouped into three blocks or divisions, these also are interconnected. Staff training is common to each division, while the manufacture of surplus milk besides being covered in practice by the technical group, is also intimately a concern of the commercial section of the business.

The adaptation of such a large organisation to smaller undertakings, either general or specialist in their scope, is, of course, the function of the manager of such a dairy, and this article will examine particularly the application to pasteurising and bottling dairies.

It must be stated primarily that irrespective of the size or scope of the dairy there are certain principles to which the manager must adhere. Briefly, these fall into two broad divisions, (i) Ethical and (ii) Practical, each with its appropriate sub-divisions. In the proper sequence of events the dairy manager must realise to the full his ethical obligations at the outset.

Ethical Principles. (*a*) ***Moral obligations.*** The nature of milk, its importance in national nutrition and the complete dependence on milk during one part at least of the life history of each human being, make it obligatory on the part of the dairy manager to ensure that only the best methods of handling, the best processing plant, and especially the strictest safeguards will be accorded to this most valuable of all single foods.

To understand to the full his moral obligations, in particular or general, the dairy manager is almost obliged to develop the outlook of a fanatic, for it is axiomatic that milk gives only of its best to those enthusiasts who afford the utmost thought, care, and effort to its handling and preparation for consumption.

Whatever is best for the milk he is entrusted with, must at all times be the dairy manager's policy and this doctrine must be inculcated throughout the entire organisation he is responsible for. This is no light task, but it is not impossible provided the dairy manager is sincere in this belief.

(*b*) ***Legal obligations.*** The plethora of legal acts, orders, regulations, etc., which surround a dairy manager's work and activities, are simply directed to the object of ensuring that the purity and safety of the milk supply is at all times maintained.

There are legal obligations, affecting the care, housing, and management of milking cows, the operation of milking, and methods and site of subsequent farm treatment, the mode, duration, and limits of treatment in the commercial dairy, the plant employed, the preparation for, and actual distribution of the milk, the receptacles used throughout, the quality of the milk at the various stages and also provisions for the personnel in various sections of the industry.

On examination it may be seen that these complex obligations can be followed more or less logically to a successful conclusion.

(*c*) ***Economic obligations.*** The economic obligations do not mean carrying out the work at the lowest possible costs. True economy is only obtained by satisfying the moral and legal obligations in full with the lowest possible waste of time, material, labour, and plant.

The obligations in this sphere, therefore, lie in selecting and formulating methods of work, etc., which primarily and fully meet the previous obligations in a practical and non-wasteful manner. For instance, in preparing a 3000 gal. milk tank, after use, for its next period of duty, morally the manager is obliged to bring it as near as possible to a state of absolute cleanliness and sterility. Legally the required sterility could be achieved by filling the cleaned tank with boiling water to ensure that all surfaces coming into contact with milk were scalded with this medium. This method is, however, neither practical nor economic so other means must be employed.

The economic obligations which a dairy manager must observe are mainly to ensure that the full benefit of whatever milk process is performed, will be obtained. In a pasteurising and bottling dairy for example, it is essential that each time the plant is brought into contact with milk it will (i) be entirely free from pathogenic organisms ; (ii) not significantly detract from the keeping quality of the finished product.

The moral and legal obligations require that these standards be met *seriatim*.

Consideration must now be given to the practical principles.

Practical Principles. The work to be performed falls broadly into three divisions : (1) technical ; (2) hygienic ; and (3) commercial.[1]

(1) ***Technical.*** In a pasteurising and bottling dairy the manager must ensure that the technique required is adequately met, not only for the two processes named but also for the other supporting processes, *e.g.* power, refrigeration, etc.

Fig. MPD 1 shows the main headings of the work performed which come within the technical divisions. These are the collection and transport of milk from farms, the operation of country creameries (depending largely on the size of the business), the treatment of milk at all its different stages of handling, the manufacture of surplus milk, *i.e.* milk not required for liquid sale, actual processing of milk for retail depots or customers, the selection of new dairy plant and its erection and maintenance, and the training of personnel to maintain an adequate qualified staff for part or any of this technological work.

In modern dairies the trend is certainly towards more and more of the technical work being performed by new and ingenious plant, which, while replacing to an increasingly greater degree the need for staff skilled in the technique of dairying as was previously known, is bringing with it a need for technical staff, skilled in the complex maintenance and control of such machines.

(2) ***Hygienic.*** The work of this division as shown in Fig. MPD 1 comprises (i) farm inspection to ensure that the high hygienic quality of milk as it comes from the healthy cow's udder is maintained right from the outset ; (ii) the commercial dairy aspects and functions under the National Milk Testing and other Control Schemes ; (iii) rendering milk and milk products safe for consumption (the main object of this division) ; (iv) the selection of plant from the hygienic standpoint ; (v) the laboratory control of plant operation and maintenance to ensure constant hygienic efficiency (and also of the processed products) ; and (vi) the training of personnel for these hygienic duties.

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[1] This grouping of functions is ably described in *The Milk Problem*, Bendixen *et al.* (Vol. VI, No. 3, League of Nations Bulletin of Health Organisation, June, 1937).

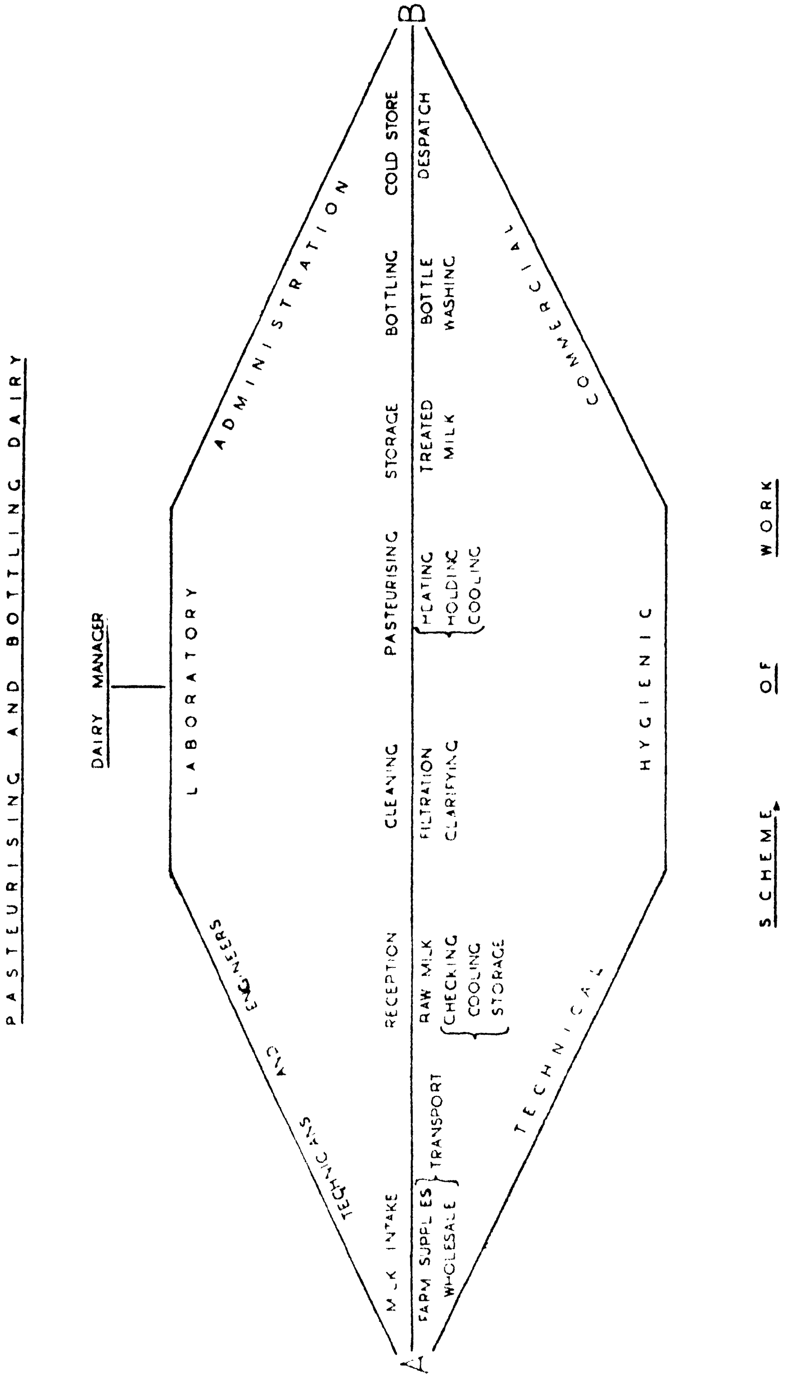

PASTEURISING AND BOTTLING DAIRY
DAIRY MANAGER
LABORATORY
ADMINISTRATION
ENGINEERS AND TECHNICIANS
TECHNICAL
HYGIENIC
COMMERCIAL
A
B
MILK INTAKE
FARM SUPPLIES
WHOLESALE
TRANSPORT
RECEPTION
RAW MILK
CHECKING
COOLING
STORAGE
CLEANING
FILTRATION
CLARIFYING
PASTEURISING
HEATING
HOLDING
COOLING
STORAGE
TREATED MILK
BOTTLING
BOTTLE WASHING
COLD STORE
DESPATCH
SCHEME OF WORK

FIG. MPD 2.

Step by step with the advancement of scientific and medical knowledge and research, the scope, efficiency, and technique of the hygienic division grow and are intensified. The vulnerability of milk lies in its excellence. Its nutritive properties and physical characteristics make milk an only too efficient medium for the dissemination of pathogenic and allied organisms. In the light of this, then, the need for the hygienic division requires no further elaboration.

(3) ***Commercial.*** Some of the main functions which fall naturally into the commercial division are set out in Fig. MPD 1, *viz.* : The supply of milk from producers, wholesalers, Milk Marketing Board, etc., the sale and disposal of processed milk products, the service to consumers, publicity and advertising, the training of personnel and general internal economy (comprising factory management, employment and control of labour, general business organisation, etc.).

The commercial principles are simply then the means of ensuring that the dairy functions on sound business lines.

Whilst, therefore, the importance of this division is fundamental, care must be taken to avoid the temptation of giving it undue prominence to the detriment of the technical and hygienic divisions. Modern distributive demand and competition have largely helped to combat this enticement, and these factors, together with the adoption of the principles and findings of scientific knowledge, have been mainly responsible for the marked increase in the efficiency of present day undertakings.

The problems which a dairy manager is faced with in meeting these obligations are interesting, varied, sometimes well nigh impossible of solution, and at all times exacting in their demands for attention and provision. It is undoubtedly true that a dairy manager's position is no sinecure but an occupation requiring unusual aptitude and assiduity.

The work of the dairy must normally be completed on every day of the year, under conditions which vary seasonally and climatically. Every day the output must be attained despite delays, breakdowns, alterations, and a multiplicity of factors beyond the control of the manager. Staff must also be found for each and every day.

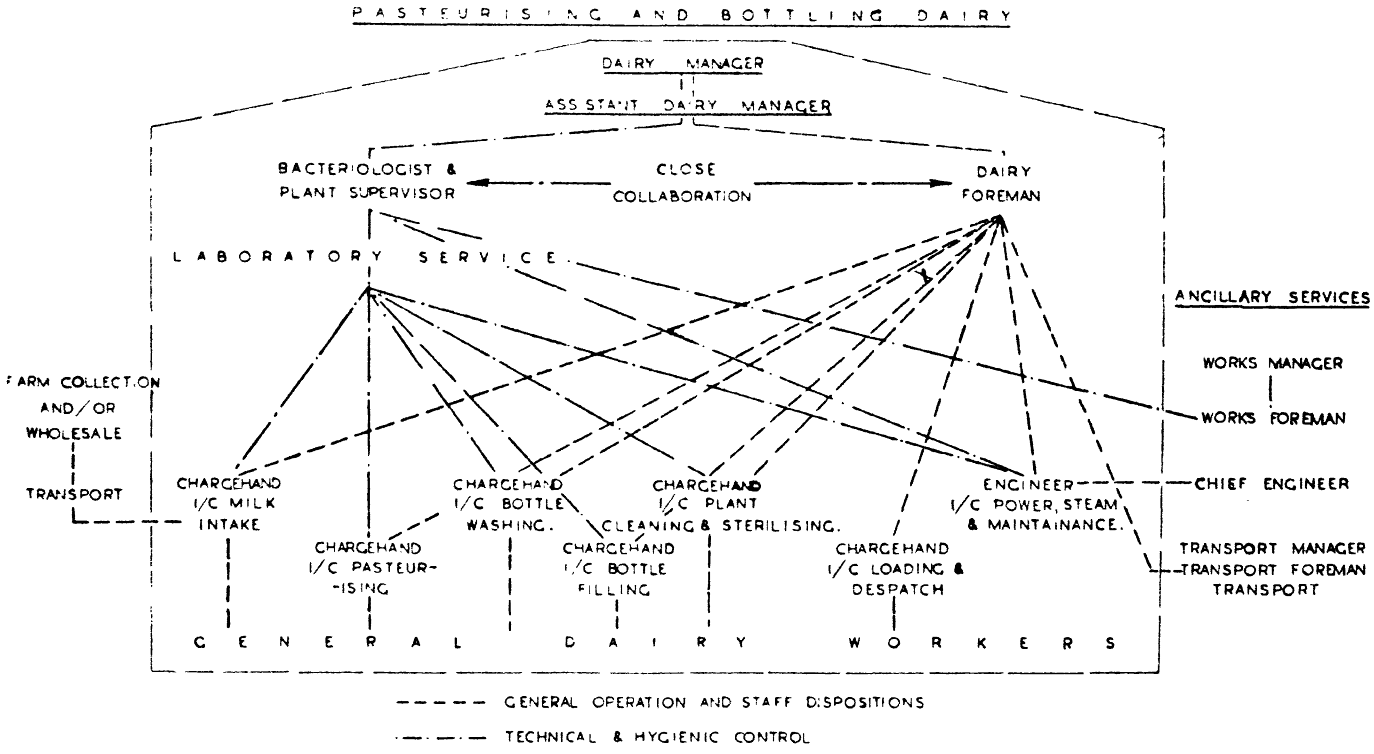
With these ethical and practical principles well to the forefront of his mind, the manager of a pasteurising and bottling dairy must now devise a routine working plan. The scheme of work to be performed is set out diagrammatically from A to B in Fig. MPD 2.

The milk intake, in the larger concerns, would come usually direct from country creameries and/or wholesale depots ; in the smaller undertakings, farm collection and transport would normally operate from the pasteurising and bottling dairy, wholesale supplies being relied on for accommodation or balancing requirements. Again, in the larger dairies the raw milk on reception might be checked, cooled, and stored. Filtration or clarifying might in either large or small dairies be carried out separately before the pasteurising process proper, or as is the more normal practice, this mechanical cleaning would be incorporated into the pasteurising process.

The remainder of the scheme of work, *i.e.* pasteurising, treated milk storage, bottle washing and bottling, cold storage and despatch would be common to large and small dairies with the possible exception of cold storage, which in the larger concerns would probably be a function of the retail depots. The three main divisions into which this scheme of work broadly falls are shown, as also are the three staff sections to deal with each division.

In order to complete his working plan, the dairy manager must now turn his attention to the general operation, technical and hygienic control, and the necessary ancillary services required to carry out this working scheme. Fig. MPD 3 shows these points in a large pasteurising and bottling dairy.

In the example shown, the dairy manager operates through his assistant manager, the latter being immediately in contact with the bacteriologist and plant


PASTEURISING AND BOTTLING DAIRY
DAIRY MANAGER
ASSISTANT DAIRY MANAGER
BACTERIOLOGIST & PLANT SUPERVISOR
CLOSE COLLABORATION
DAIRY FOREMAN
LABORATORY SERVICE
ANCILLARY SERVICES
WORKS MANAGER
WORKS FOREMAN
FARM COLLECTION AND/OR WHOLESALE
TRANSPORT
CHARGEHAND I/C MILK INTAKE
CHARGEHAND I/C PASTEURISING
CHARGEHAND I/C BOTTLE WASHING.
CHARGEHAND I/C BOTTLE FILLING
CHARGEHAND I/C PLANT CLEANING & STERILISING.
CHARGEHAND I/C LOADING & DESPATCH
ENGINEER I/C POWER, STEAM & MAINTAINANCE.
CHIEF ENGINEER
TRANSPORT MANAGER
TRANSPORT FOREMAN
TRANSPORT
GENERAL DAIRY WORKERS
GENERAL OPERATION AND STAFF DISPOSITIONS
TECHNICAL & HYGIENIC CONTROL

STAFF ORGANISATION

FIG. MPD 3.

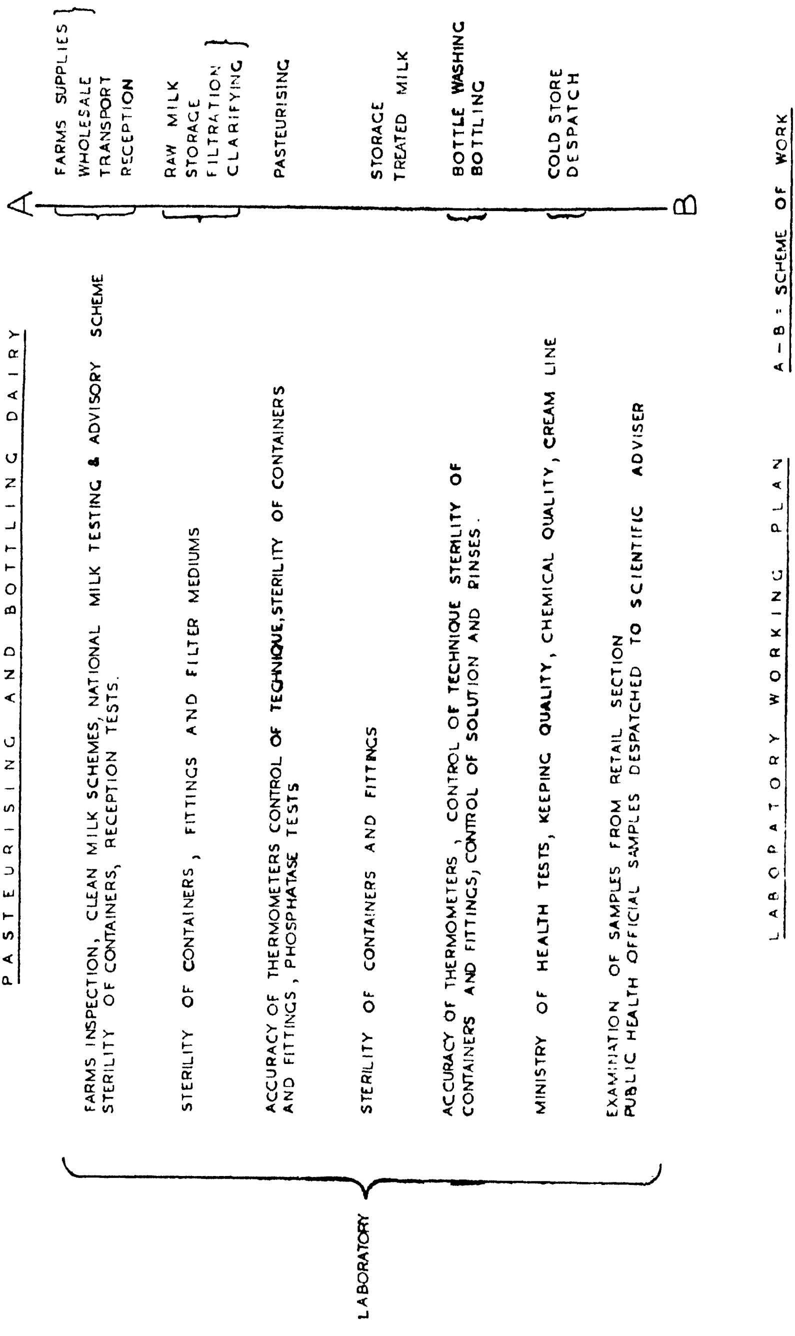

PASTEURISING AND BOTTLING DAIRY
FARMS INSPECTION, CLEAN MILK SCHEMES, NATIONAL MILK TESTING & ADVISORY SCHEME
STERILITY OF CONTAINERS, RECEPTION TESTS.
STERILITY OF CONTAINERS, FITTINGS AND FILTER MEDIUMS
ACCURACY OF THERMOMETERS CONTROL OF TECHNIQUE, STERILITY OF CONTAINERS
AND FITTINGS, PHOSPHATASE TESTS
STERILITY OF CONTAINERS AND FITTINGS
ACCURACY OF THERMOMETERS, CONTROL OF TECHNIQUE STERILITY OF
CONTAINERS AND FITTINGS, CONTROL OF SOLUTION AND RINSES.
MINISTRY OF HEALTH TESTS, KEEPING QUALITY, CHEMICAL QUALITY, CREAM LINE
EXAMINATION OF SAMPLES FROM RETAIL SECTION
PUBLIC HEALTH OFFICIAL SAMPLES DESPATCHED TO SCIENTIFIC ADVISER
LABORATORY
A
FARMS SUPPLIES
WHOLESALE
TRANSPORT
RECEPTION
RAW MILK
STORAGE
FILTRATION
CLARIFYING
PASTEURISING
STORAGE
TREATED MILK
BOTTLE WASHING
BOTTLING
COLD STORE
DESPATCH
B
LABORATORY WORKING PLAN
A – B = SCHEME OF WORK

FIG. MPD 4.

supervisor, and the dairy foreman. The required technicians for each process are shown as chargehands in charge (i/c) of the work performed, *i.e.* reception and intake, pasteurising, bottle washing, bottle filling, loading and dispatch, plant cleaning and sterilising, and in the case of the chargehand engineer, in charge of power, water, steam, and plant maintenance. The activities of the bacteriologist and plant supervisor and the laboratory service, comprise the technical and hygienic control while the dairy foreman is responsible for general operation and staff dispositions. Fig. MPD 3 shows the connections of these personnel to each of the working schemes and to the executives in the ancillary services—transport, engineers, and works and buildings.

In the smaller dairies where there is no assistant manager, or bacteriologist and plant supervisor, the corresponding duties would be carried out by the dairy manager and the dairy foreman. A rudimentary laboratory staffed by a trained tester would be essential for it is inconceivable that a pasteurising and bottling dairy would be too small to support a laboratory, nor does it appear that modern public health ideas would allow the laboratory's elimination in any such dairy. Similarly, the duties of the chargehands in a smaller dairy would be shared between the dairy foreman and the practical dairy workers, whilst mechanicians' duties might be entirely ancillary, the rudimentary duties in this respect being carried out by a handyman-stoker.

As described earlier the functions of a pasteurising and bottling dairy fall broadly into three main divisions, *i.e.* technical, hygienic, and commercial.

In practice the laboratory service would cater for the hygienic aspects, technicians and engineers would supervise the technical division, and administration in the larger units would be the concern of the general office division.

The working plan must now be elaborated for these three sections.

(1) ***Hygienic service.*** Since the process of pasteurisation is based on the fact that certain combinations of time and temperature produce a definite hygienic safeguard (*see* Pasteurisation) it will be realised that the keystone of the organisation of a pasteurising and bottling dairy is indisputably the laboratory. It is the laboratory service which shows whether the raw material is acceptable, whether the organisation and routine achieve their aim or to what extent they fall short and under what circumstances.

Fig. MPD 4 shows the activities of the laboratory in the scheme of work (set out from A to B in Fig. MPD 2). Little need be said here regarding Fig. MPD 4 since the diagram is for the most part self-explanatory, although for simplicity's sake the work of the laboratory in general dairy hygiene, *e.g.* examination of water supplies and water softeners, cleanliness of dairy buildings and dairy services, etc., selection of plant, and the training of staff, has been eliminated as also has special research on problems peculiar to the particular dairy.

(2) ***Technical service.*** In a pasteurising and bottling dairy, the term technician would include foremen, pasteurisers, sterilisers, machine overseers, raw milk reception personnel, etc., or in other words, any staff doing work which requires a certain degree of skilled knowledge and responsibility.

The engineering staff would include maintenance, erection, electrical, motor, and refrigeration engineers. They would be responsible for steam-raising equipment, refrigeration, power, water supplies and treatment, plant adaptation to technique, fuel economy, transport, etc.

Thus the technical aspects of the work in a pasteurising and bottling dairy would be catered for by technicians and engineers working in strong liaison with one another, and as shown in Fig. MPD 3 with the bacteriologist and plant supervisor and the dairy foreman.

One of the simplest examples of the need for such liaison is shown by the dictates of fuel economy. A pasteuriser who has no knowledge of or interest in where the steam comes from and how it is produced, can, by turning on a steam valve without warning, throw the boiler staff into a state of complete perplexity.

Liaison between the boiler room staff and the dairy staff can, however, achieve near-miracles in fuel economy by spreading the steam demand over the course of the working day, and cutting out those wasteful peak demands which are detrimental to the steam-raising equipment. It should also be mentioned that the rapid development and extension of mechanisation in the dairy industry has shown a definite need for a new type of mechanician, *i.e.* a dairy engineer, or in other words, an engineer who has a sound knowledge of milk and the hygienic principles required from personnel handling this highly perishable commodity.

(3) ***Administration.*** Just as milk recording is essential to planned and efficient milk production on the farm, so is clerical administration essential to a pasteurising and bottling dairy, as indeed to any other form of business. The absence of clerical administration would not of itself stop the dairy existing or operating, but it would produce conditions similar to a ship at sea without a helm.

In the larger concerns, administration would be the responsibility of a chief clerk and a sectionalised office staff and in the smaller dairies the work would probably be shared between the manager, the dairy foreman, and a clerk/cashier. The activities grouped in this division would be centred on the production and maintenance of essential records, compilation of costs, accounts, wages, and general statistics, which on analysis point the direction for future activities. Administration also serves as the liaison between the dairy and suppliers, customers, public authorities, etc., and even between the different internal sections of the organisation.

In a single unit such as a pasteurising and bottling dairy the clerical administration service would also take part in staff training, welfare, etc., and would be generally the main source of information for efficiency investigations.

A working plan for the routine daily operations having been devised and elaborated, the dairy manager should now review that work which is the particular concern of the management. It is indisputably true that a manager who is obliged regularly to take a part, however small, in the routine daily operations is not carrying out his proper functions, nor can any dairy afford to pay for the manager performing routine detail work. Re-examination, guidance, co-ordination, elimination of waste, promotion of efficiency, and planning are his most valuable tasks to which he properly must turn his attention having once created his routine working plan. The following review of the purely managerial functions are not set out in any recommended order of priority, for this depends on the nature of the business, the competition met, circumstances prevailing at any one time and the knowledge produced by research work, either external or internal.

(i) ***Re-examination.*** In any business and especially in an expanding one, it is essential to have an ordered system of procedure so framed that it will as far as possible stand any strain and be capable of meeting and legislating for any contingency. The need for constant re-examination of the working plan under these conditions is therefore self-evident and ensures that this plan will allow for additions to the structure as the necessity arises, either from new scientific findings, development in technique, or extra demands for output.

Regular and comprehensive reports from all sections and services provide an accurate picture of the efficacy of the working plan. Such reports should, of course, include records of work done and also difficulties experienced. Personal presentation of these records should be encouraged as far as possible, for this establishes the principle that the dairy management is vitally concerned with the information and it is a great influence in emphasising the importance of the job to the worker concerned.

Again, personal observation by the dairy manager of his plan at work will not only provide information as to its adequacy but also assist towards immediate improvements to prevent difficulties which might arise. There is no doubt such regular routine inspections, both surprise and scheduled, are of great benefit to, and indeed, expected by the entire staff.

(ii) ***Guidance.*** It is essential that the dairy staff understand the working plan and the methods employed, be able to carry them out day after day and appreciate fully the effects of failing to work correctly. These facts cannot be emphasised too strongly for the effectiveness of any working plan is based entirely on the efficiency of the workers. Time and money spent on staff tuition on this point and demonstration of the ill-effects resulting from inefficiency will always be found well worth while. Not only do technicians require to be trained but also the ordinary dairy workers should be adequately tutored to the necessary degree of efficiency in work and habits. In other words, the staff should be made fully aware of what to do and why they do it.

A sense of responsibility and conscientiousness can provide that very necessary lubrication for the smooth working of the plan.

Adequate provision for staff welfare is of the utmost importance here for no single factor is more conducive to fostering team spirit, loyalty to the employer, or the workman's pride in his job, all of which are invaluable. Further, staff welfare, properly planned, will bring the manager into contact with his staff when they are off duty, a most desirable feature. The ability to choose the right executives and working staff is of the greatest importance to successful dairy management, and observations at work, progress under tuition, and staff welfare all play their part in providing the necessary information for this purpose.

(iii) ***Co-ordination.*** In a pasteurising and bottling dairy of any appreciable size, the manager will rightly sectionalise his organisation as shown in the working plan described earlier. There is a danger, however, that the section chiefs, although well trained and successful in running their own departments will acquire a somewhat parochial outlook, immersed as they are in the day to day routine of their work.

Whilst the dairy manager must maintain at all times a clear conception of the needs of the business as a whole, the broad policy he is to follow and the objective towards which the dairy is directed, much of his practical information will come from the sectional chiefs. In order to avoid biased opinion, which specialist workers might induce, co-ordination of the different sections' activities must be achieved in order to maintain unity of purpose and to ensure that planning for the future is correctly balanced and will adequately meet the requirements of each and every unit in the organisation.

Much of the dairy manager's success lies in his ability to choose his staff and co-ordinate their efforts. It need hardly be said, therefore, that a broad knowledge of the industry, rather than a specialist view-point will facilitate this function of co-ordination

(4) ***Elimination of waste.*** If the elimination of waste in time, material, and labour, is to be successfully achieved the dairy manager must have reliable and adequate costings on which to base his actions.

Although such expense analyses are required in cash value for the purpose of keeping a watch week by week on what is happening in the dairy, they should also be compiled on the basis of quantities of materials consumed per " x " gal. of milk handled. The following are representative illustrations : (*a*) Capping foil—caps obtained or bottles capped per lb. weight used. (*b*) Coal, coke, oil—gal. processed per ton used. (*c*) Electricity—gal. processed per unit used. (*d*) Water—gal. used per gal. of milk treated. (*e*) Wages—cost per gal. handled. (*f*) Bottle-washing detergent—lb. used per 1000 bottles washed.

To obtain such information it may be necessary to meter the various services to the different sections of the dairy, in order to calculate accurately the steam, water and electricity used in bottle washing, bottle filling, milk pasteurising, etc. Sectional costings are, of course, necessary and the consumption in the different services can be thus determined. Labour costs, particularly of general dairy workers employed in more than one section or on a multiplicity of jobs throughout the day, can be accurately obtained by utilising distinctive time cards for specific sections or occupations. Thus two different cards would be used by a worker employed on bottle washing for one part of the day and on cleaning bottle-washing machines for the remainder of the day.

Having obtained accurate, simple, and practical costings records, the examination of these and experiments on points showing excessive consumption can then be carried out.

Generally it will be found that automatic controls or regulated feeds will be less wasteful than manually operated similar functions. Nevertheless, there is a great need for efficient supervision and inspection of such automatic devices. Staff consciousness of the sources and means of waste and the method of preventing these, are the whole solution to this problem. The fixing of definite standards of consumption or better still targets to be strived for, especially if the achievements are charted and displayed, are normally effective in achieving this purpose.

The most popular method of judging the efficiency of a dairy plant, staff, or management, is by the Milk Leakage Figures. Milk leakage or wastage is the difference between the amount of milk received and the amount of milk dispatched and/or in storage at the end of each working day, taking into account the opening and closing stocks. The figure of such wastage is usually compared either with the amount of milk received or the daily output corrected by the difference of the opening and closing stocks.

Milk leakage is one source of waste which can easily be demonstrated to the dairy staff, for much of this wastage can be observed actually taking place, *e.g.* incomplete drainage of churns, leaks in machines and pipe lines, breakages, and spillage. There are, however, many factors which go to make up milk leakage and the importance of curtailing such loss to minimal proportions is the subject of frequent dissertations by various writers. Suffice it to say here, that this problem must be tackled with equal, if not more vigour, than the other sources of waste.

Regular examinations of costings analyses and constant efforts to reduce waste are vital to the success of a business.

A word here regarding possible waste in the compilation of records and even costing systems may not be out of place. Accurate and simple records are required but every care must be taken to ensure that the records or costings system remain the servant (so to speak) of the business, and not by their complexity become tantamount to the master.

(5) ***Promotion of efficiency.*** In the general promotion of dairy efficiency the contributions of an adequate working plan, its regular re-examination, managerial guidance, co-ordination of staff efforts, costings, incorporating production and economy targets, have already been described. While it is true, and rightly so, that a dairy manager must always adopt the attitude that the efficiency of his organisation is never good enough, it is equally correct to say that he must use all available means to assist the efforts made in striving for the ideal. Besides the above contributory factors, certain allied scientific principles and results of practical research on this problem must also be enlisted in his drive.

In modern business organisation remarkable results have been obtained in this field by the application of time and motion study and the principles of industrial psychology. It has been shown in purely repetition work, for example, the elimination of the need for the operator to observe, think, and make a decision, before transferring an article from one position to another, has resulted in astounding increases in output. It is also worthy of note how very often the need for these mental processes can be simply eliminated, and the next logical step—complete mechanisation—easily achieved.

The principles of industrial psychology as an aid to speedy and accurate staff selection for various jobs are far and away more economical and reliable than the slower and wasteful trial and error methods.

It will be obvious that an Institute of Dairy Technology would be of invaluable assistance to dairy managers, not only in disseminating these modern efficiency principles, but also in giving practical examples of their application.

Planning. Regular and frequent reconsideration of the trade objective will enable the dairy manager to plan for both immediate and future progress towards this target.

The manager of a pasteurising and bottling dairy must endeavour to ensure that his dairy's productive capacity never lags behind the demand from his customers or retail section. It should be possible for the capacity of the plant to be increased without interfering with the working of the dairy and the normal output. Production potential should be at least 3 years ahead of the present output and so estimates must be made of what the demand is likely to be at this period ahead.

In his planning function, therefore, the manager must consider either extensions to the existing plant and buildings or the erection of a new and larger dairy. In this respect then, contact should be maintained with dairy plant development and also through architects and specialists, with new materials which are, or will be, suitable for flooring, walls, etc., in a commercial dairy.

Plant layout must be considered in the light of the technical, hygienic, and commercial requirements. A manager in preparing a general arrangement drawing of dairy plant is bound by certain well established principles, *e.g.* short pipe lines, short conveyors for clean bottles, avoidance of cross traffic on dairy floors, accessibility of one section of the plant from another, and many other fundamental considerations.

While these principles are in the main adequately provided for in the majority of dairies, there are certain less obvious, though none the less real requirements which only too often appear to be overlooked or merely partially catered for, *e.g.* the maximum utilisation of natural daylight, adequate ventilation and efficient air conditioning, clean-cut, impervious walls and ceilings (without the alleged decoration too commonly seen), smooth, hard-wearing floors laid to adequate falls, efficient, accessible and easily cleaned channels, gullies, drains, and gutters.

It must be stated in fairness to managers and architects of many existing dairies that the vast majority of these requirements would have been efficiently included in the buildings and layout if they had been able to build an entirely new dairy on an adequate site. Only too often, however, the new dairy is merely an extension of an existing old-fashioned one, or worse still, a reconversion of a building put up for an entirely different purpose. In such cases the manager is obliged to incorporate as many of the above principles which conditions allow, and others must go by the board, not from choice but of necessity (*e.g.* adequate floor space sometimes appears to be severely rationed when a new dairy is projected and this disadvantage right from the inception is a bugbear throughout its entire existence).

Simply then the guiding principle here is the eradication or correction of any arrangement which prevents the easy maintenance of the building, etc., in the hygienically clean state demanded by safe milk handling.

Conclusion. Finally, considering the functions of a manager, in whom is vested the management of a pasteurising and bottling dairy, it should be said that his responsibilities as regards public health must always be to the forefront of his mind. Every effort should be directed to producing the best possible article at an economic price. By so doing two vital objects will be achieved: (1) The obligations to the public will be fulfilled. (2) The business will be likely to increase by reason of the high quality product turned out.

The whole complex organisation so built up must of necessity work as a team and the sole secret of such efficient activity is obviously a good dairy manager with a sound, general education and adequate training in commercial, hygienic, and technical matters.

It will, of course, be realised that in a fairly short discourse only the essential points can be brought out and occasionally merely indicated. Much detail must be omitted though in practice the importance of these items can be very real.

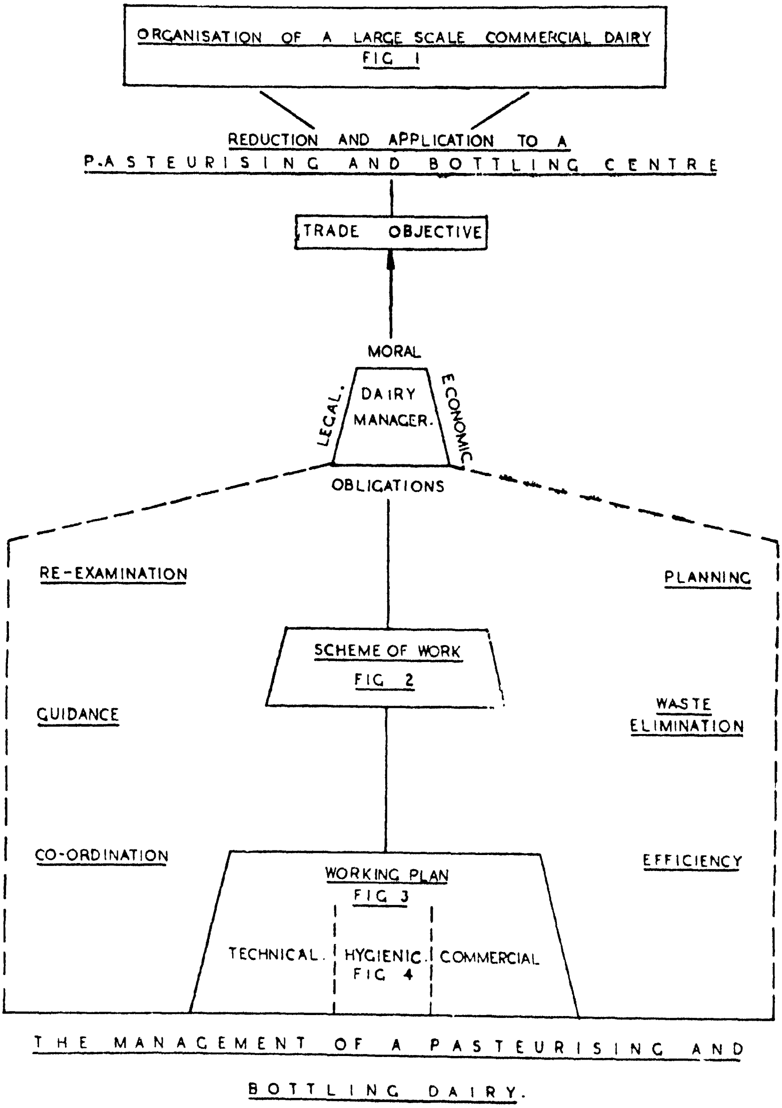


FIG. MPD 5.

Summary. The basis of this discourse is set out diagrammatically in Fig. MPD 5.

A typical organisation of a large scale commercial dairy is shown (Fig. MPD 1) and the necessary reduction and application of this organisation to a pasteurising

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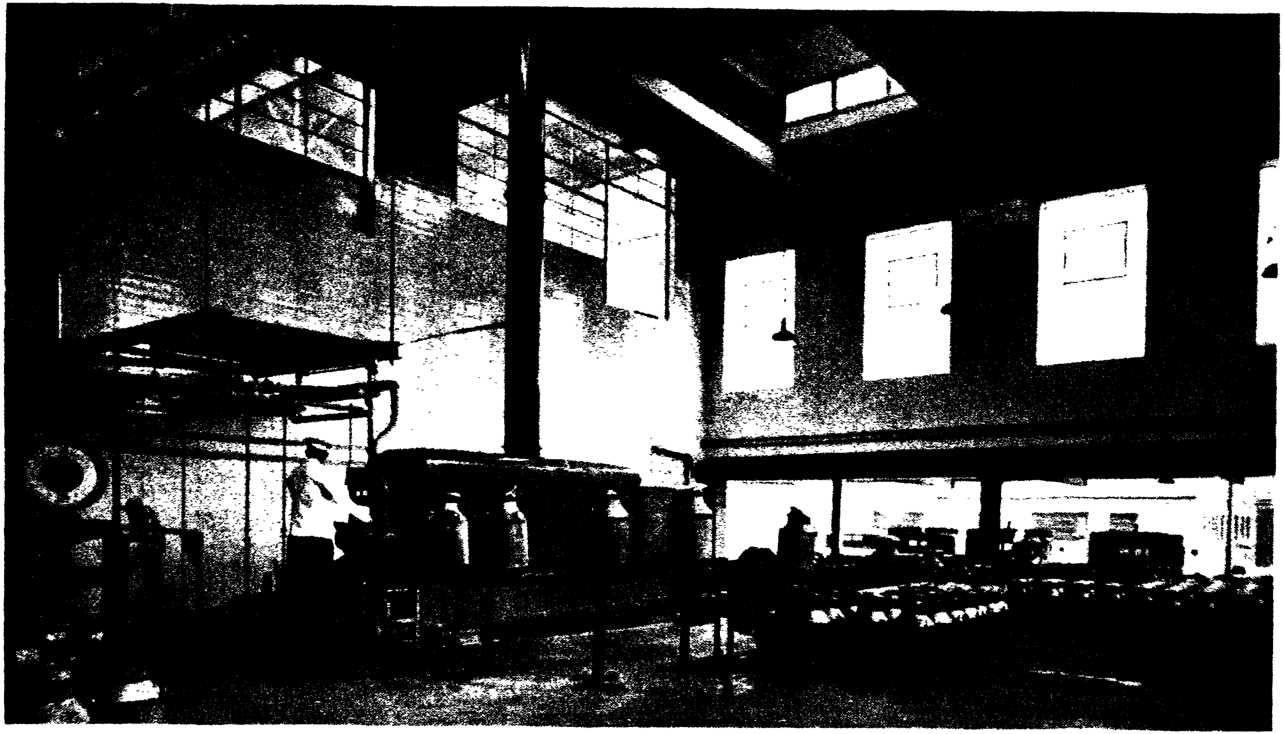
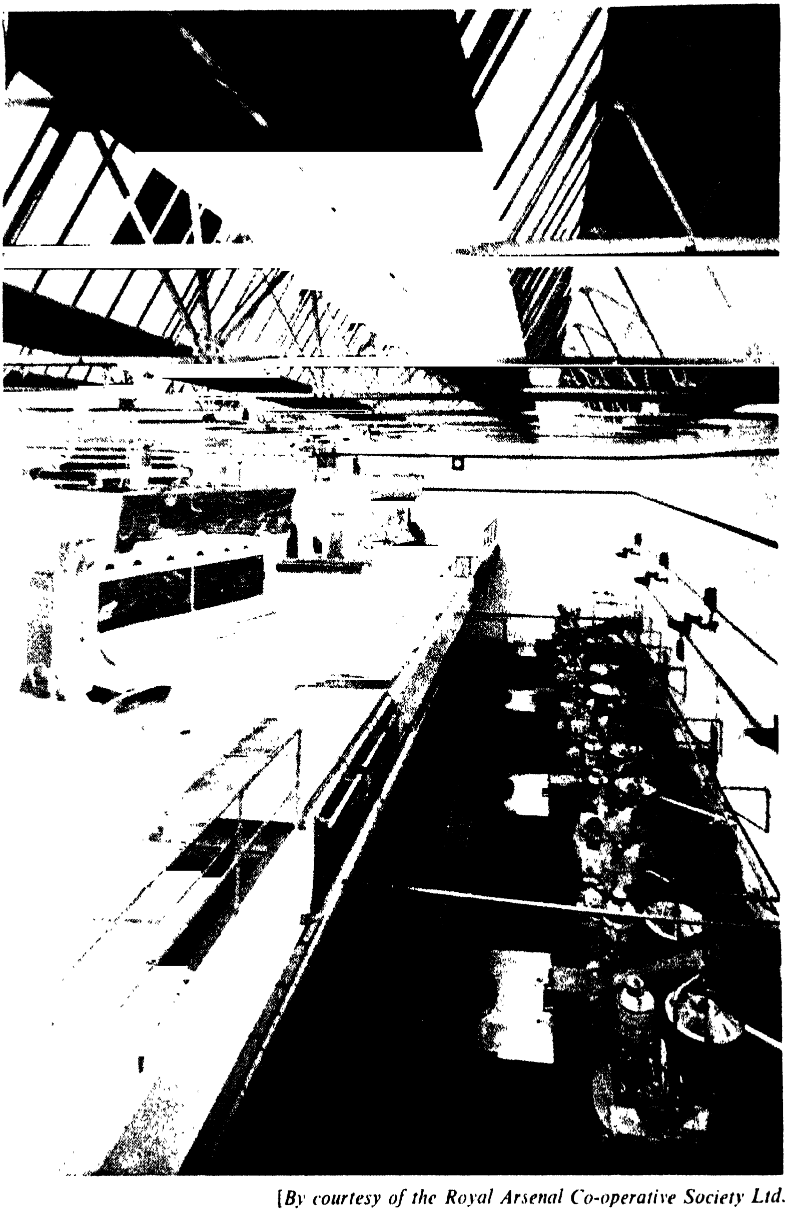


[*By courtesy of Bristol Co-operative Society Ltd.*

FIG. MPD 6.—*A Lofty and Spacious Churn Receiving Room with Good Natural Lighting.*



[By courtesy of the Royal Arsenal Co-operative Society Ltd.

FIG. MPD 7.—*Bottle Filling and Capping Room with Good Height over the Fillers. The Finished Milk Pipe Lines are as short as possible.*

and bottling dairy has been used as the method of elaborating the management of such a unit. Further simplification is aimed at by presuming the management is vested entirely in the dairy manager.

Fig. MPD 5 shows the resulting organisation moving towards its trade objective and headed by the dairy manager working within his moral, legal, and economic obligations. The scheme of work to be done (Fig. MPD 2) is shown and the necessary, all important, working plan (Fig. MPD 3) for the performance of same is explained in its three appropriate divisions, *viz.* hygienic (Fig. MPD 4), technical, and commercial.

Embracing and catering for the whole are the main managerial functions in an organised unit, *viz.* re-examination of the working plan, guidance of staff, efficiency promotion, co-ordination of efforts, elimination of waste, and planning for the present and future trade objectives and organisations.

Figs. MPD 6 to 9 show typical layouts of a milk-receiving room, a bottle-filling room, a boiler house, and a refrigeration plant. *See* Bottle washing ; Churn washing ; Costings ; Dairies, design of ; Electrical equipment ; Legal aspects ; Management of creameries ; Mechanical handling ; Pasteurisation ; Refrigeration ; Steam raising.

MANUFACTURE. *See* Butter ; Cheese ; Condensed and evaporated milk ; Management of creameries ; Milk marketing ; Milk powder ; Quality payment ; Stability ; Utilisation.

Ref. : Mork (1944), *Yield, Overrun and Losses in Processing Milk and Manufacturing Products in Creameries* (in Norwegian), Oslo.

MANGANESE. A trace element in milk, possibly essential to life.

MANURE. *See* Faeces, bovine ; Management of cattle.

MARE'S MILK. *See* Mammals.

MARGARINE. This well-known important fatty food, made as an imitation of and substitute for butter, was invented by the French chemist Mège Mouriés in 1869—B.P. 2157, 1869. The statutory definition of margarine in this country is " any article of food, whether mixed with butter or not, which resembles butter and is not milk-blended butter ". The resemblance to butter of margarine, as it is made in this country and in most margarine-consuming countries, is very close ; in appearance, texture, fat content, moisture, milk solids, flavour, nutritive and culinary properties, it is difficult to distinguish between the products. The principal difference is in the composition of the fat, which in butter is all from the milk fat, whereas margarine fat, although up to 10 per cent. butterfat is permitted in this country, is generally a mixture of various refined vegetable oils and fats, animal fats and hydrogenated oils, selected and proportioned to give the required physical characteristics.

The manufacture and sale of margarine is subject to statutory regulations among which are maxima for butterfat content (10 per cent.) and moisture (16 per cent.) ; chemical preservatives, except common salt, are prohibited (dispensation from this regulation was granted during the recent war when the use of 0·25 per cent. boron preservative was permitted) ; factories and premises must be registered, and packages and wrappers must be specially branded and marked. Until 1887 the product, mostly imported, was sold under the name Butterine, but that year the first Margarine Act decreed that the name should be Margarine. In addition to special acts, the general regulations of the Food and Drugs Act and the Public Health Regulations also apply to margarine.

A prize offered in 1867 by the French government under Napoleon III for a suitable substitute for butter which could be produced cheaply and on a large scale for supplying to the poorer classes and the armed forces, prompted Mège Mouriés to study the metabolic processes by which the food of the cow contributed to the formation of butterfat in the milk, and the chemical and physical processes by which this was made into butter. From observations that starving cows still yielded milk with practically the normal percentage of fat he concluded that the source of the milk fat was the body fat of the cow and that this, by enzymic action in the body cells and in the mammary glands, was fractionated into a lower melting fraction, which was dispersed into the milk plasma to yield milk, and a higher melting fraction which served the animal as a source of energy. He then decided to imitate these processes *in vitro*, using an alkaline extract of pig's stomach for treating the tallow at body temperature and pressing out the lower melting fraction from the treated fat by hydraulic pressure. This fat, which he thought was the glyceride of margaric acid, was then mixed with water and skim milk in the presence of a small quantity of minced cow's udder, about 0·15 per cent. He certainly got a creamy emulsion which, with the proportion of fat he used, contained 40-50 per cent. fat, but contrary to his expectation, the fat was not butterfat as it did not contain any of the low-molecular and volatile fatty acids characteristic of butterfat. He postulated that these were degradation products highly susceptible to rancidity and that his fat was of better keeping quality. Having obtained his cream he proceeded to churn it in a conventional butter churn, and when the " butter " granules appeared cold water was added to assist separation of the artificial butter from the buttermilk, which was drained off, and the solid product was salted and kneaded.

Although Mège Mouriés did not succeed in making butter by his process, he did produce the prototype of what was later to be known universally as margarine; considerable industrial developments soon followed, and apart from the use of organic gland preparations, which the inventor himself soon abandoned, the large scale methods closely followed for many years the original ones, namely preparation of a suitable fat, emulsifying and churning this with milk, generally skim milk, solidifying the emulsion by chilling, and kneading and plasticising the product.

The original fatty raw material, known in this country as oleomargarine or oleo, in U.S.A. as oleo oil, was soon supplemented or replaced by many other oils and fats, and as the art of refining developed, and particularly when hydrogenation of oils to controlled degrees of saturation and hardness was perfected, the range of suitable fats and oils was widely extended. The most important fatty raw materials are coconut, palmkernel and palm oils, which are solid in this country, groundnut, cottonseed, soyabean and sunflower oils and their hydrogenated solid derivatives, and hydrogenated whale oil. Oleo, rendered beef tallow known as *premier jus*, and lard are also used, but to a lesser extent and mostly for speciality margarines, *e.g.* for confectionery purposes.

The manufacturer prepares from the fats and oils available to him, with due regard to the economic aspect, a mixture which will give a fat with physical characteristics as similar to butterfat as possible. While the melting point of butterfat (abt. 31° C.) is fixed by the nature of the fat in the milk from which it is derived, and varies only within a few degrees C., the margarine manufacturer can by suitable adjustments of the fat and oil blend, vary its melting point to meet seasonal temperature fluctuations, keeping it, however, below body temperature to avoid interference with digestibility. Another feature to be considered is the glyceride composition of the blend, as in order to obtain in the margarine the correct consistency over a suitable temperature range, there should be within that range an appropriate ratio of liquid and solid glycerides, for the determination of which calorimetric or dilatometric methods are employed. From the point of view of chemical composition, fats with a high proportion of fully saturated high-melting glycerides should be used only in moderate proportions, and oils with more than 2-3 per cent. linolenic acid in the glycerides are avoided because of their pronounced susceptibility to oxidation.

Skim milk or reconstituted skim milk powder is the preferred aqueous phase, although there are countries where the use of milk products is prohibited. As the milk is used as a flavouring ingredient as well as to provide the curd, which is important when margarine is used for certain culinary purposes, margarines made with water generally contain some synthetic flavouring. The preparation of the milk follows the methods used for preparing ripened cream for butter making. The milk solution is pasteurised and cooled to a suitable temperature for inoculation and ripening with cultures of lactic acid bacteria at 18-24° C. The proportion of inoculum varies, but is generally 1 to 5 per cent., and the preferred cultures are a mixture of good acid producers, such as *Streptococcus cremoris*, and aroma formers, such as *Streptococcus paracitrovorus* and *B. diacetylicum*, which in symbiosis and when the milk contains the necessary nutrients produce lactic acid, diacetyl, acetyl methyl carbinol and other aroma compounds as well as volatile acids. When the right acidity and aroma are developed, as a rule at a *p*H value of about 4·3 to 4·5, the ripened milk is cooled and ready for emulsification with the fat blend. The proportions used in modern processes are 16 to 18 per cent. of the milk or aqueous phase to 82 to 84 per cent. fat blend.

Emulsification is effected either in batch plants or churns, jacketed vessels of tinned steel, aluminium or stainless steel, provided with speed-regulated agitators, or in continuous emulsifiers with proportioning devices for fat blend and milk. In the batch churns, variations in the rates of adding the constituents and in temperatures can be regulated so as to obtain either a water-in-fat type of emulsion or a mixed emulsion of this type and the opposite, and also to initiate a partial crystallisation of the emulsion. The continuous emulsification does not permit temperature variations during the process which lasts only a few seconds and yields directly a water-in-fat emulsion. Artificial colouring, either a vegetable colouring matter or one of the approved synthetic dyes, is added in the churn or to the fat blend, and sometimes emulsion stabilisers, such as egg yolk, lecithin, mono-glyceride, etc., are added at the same time.

The solidification and crystallisation of the emulsion was originally done by spraying cold water on the emulsion as it left the churn, or by running it into a tank of ice water, but this method has in most factories been replaced by the cooling drum method in which the emulsion is spread as a thin layer of about 0·2 mm. or less—on the surface of a rotating cylinder chilled internally by means of brine or expanding ammonia. In recently developed plants (*see* below) the cooling and emulsification are done simultaneously in closed tubes. In the cold water spray method the solidified emulsion is in the form of granules, the cooling drum delivers it as sheets or flakes of crystallised fat, and the cooling tubes as a soft but rapidly hardening paste.

While the last-mentioned method delivers the margarine ready for packing, the granular or flaky material from the other cooling processes requires working and kneading on various types of machines for consolidation and plasticising. Such machines may be single, double or multiple pairs of wooden, steel or porphyry rollers where the margarine passes between the rollers with differential speed, or they may be horizontal, wooden, revolving tables, similar to butter workers, on which the product passes between the table surface and corrugated or fluted rollers or rollers studded with pegs. Another type, often used for final kneading and known as the margarine blender, is a tinned or stainless steel trough provided with paddles of special twisted design and revolving rapidly at differential speeds. This machine often works under vacuum to prevent air being beaten in during working. The blender also permits the incorporation of salt, preservative and various ingredients where these have not been added at an earlier stage. In recent years, kneading machinery of the totally enclosed type and made of corrosion-resisting metal, has been introduced in many factories; the flaky material falls into a hopper and from there is fed continuously to a section where it gets a preliminary working by means of worms which convey and compress the margarine into a section where it is kneaded and plasticised by passing through perforated stationary plates, between which cutter knives revolve; finally the margarine is pressed out through an orifice ready for packing.

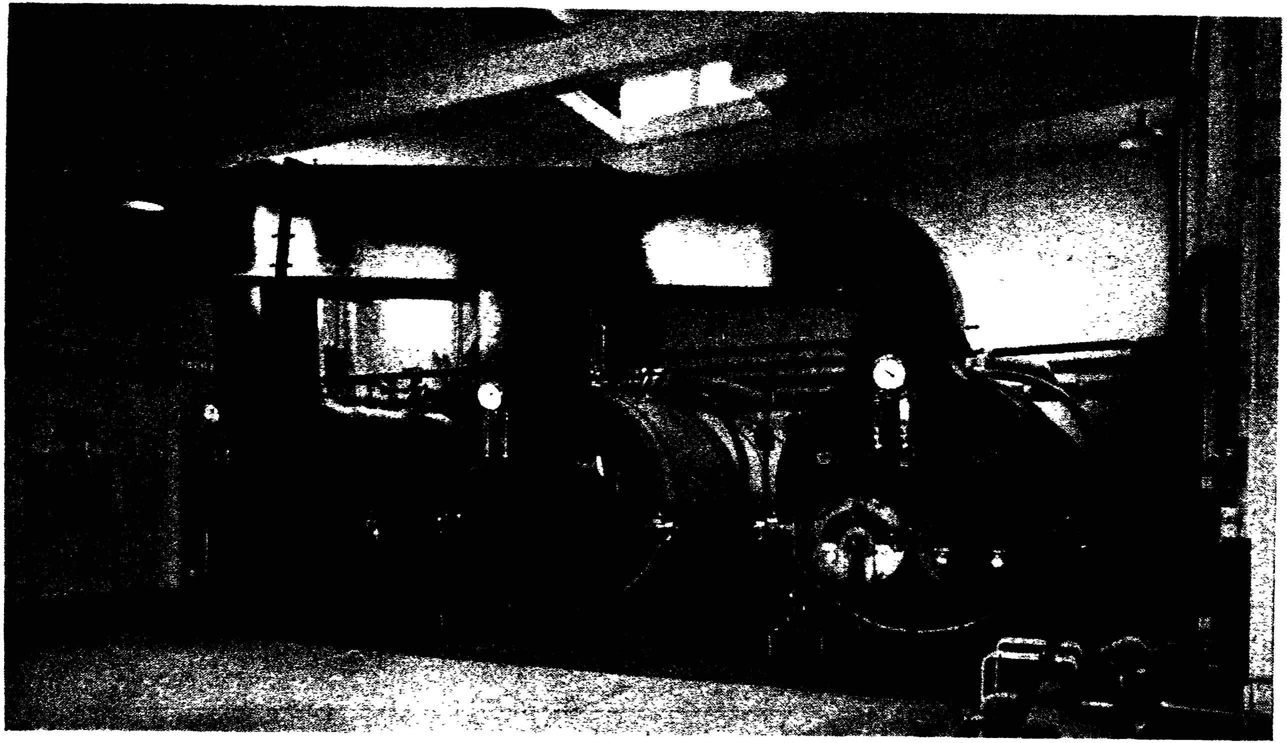
For packing margarine in bulk, parchment-lined wooden or cardboard boxes of 14 lb., 28 lb. or 56 lb. are mostly used. Small packets are wrapped on high-speed, combined shaping and wrapping machines and the ½ lb. brick shape is customary in this country, whereas in some countries the cube shape is compulsory. During the last few years excellent British wrapping machinery has been introduced, while in pre-war years such machinery was practically all imported.

The principal systems of plant for manufacturing margarine are the following:

1. The churn-drum-multiplex system in which an emulsion is formed in the churns, ranging in working capacity up to two tons, and adjusted finally to a temperature between melting and setting points of the fat blend. This emulsion of creamy consistency is pumped to a feeding trough, where it is picked up by a roller of about 1 ft. diameter, warmed to a temperature similar to that of the emulsion, and spread on a large refrigerated roller with a surface temperature of about − 15° C., and revolving in the same direction as the feeding roller. The emulsion solidifies on the large roller, is carried round nearly one revolution until it meets a scraper placed just under the feeding trough and is removed in flaky sheets and collected in containers underneath. After a short rest during which the flakes increase in temperature from about 0° C. to 8-10° C., owing to release of latent heat of fusion from the supercooled fat, the loose crystalline material is consolidated, worked and plasticised on the rollers and blenders and again rested for a short period prior to being packed. It will be seen that this system consists of four distinct and separate steps. Figs. Ma 1 to 4 show this type of plant in a modern factory.

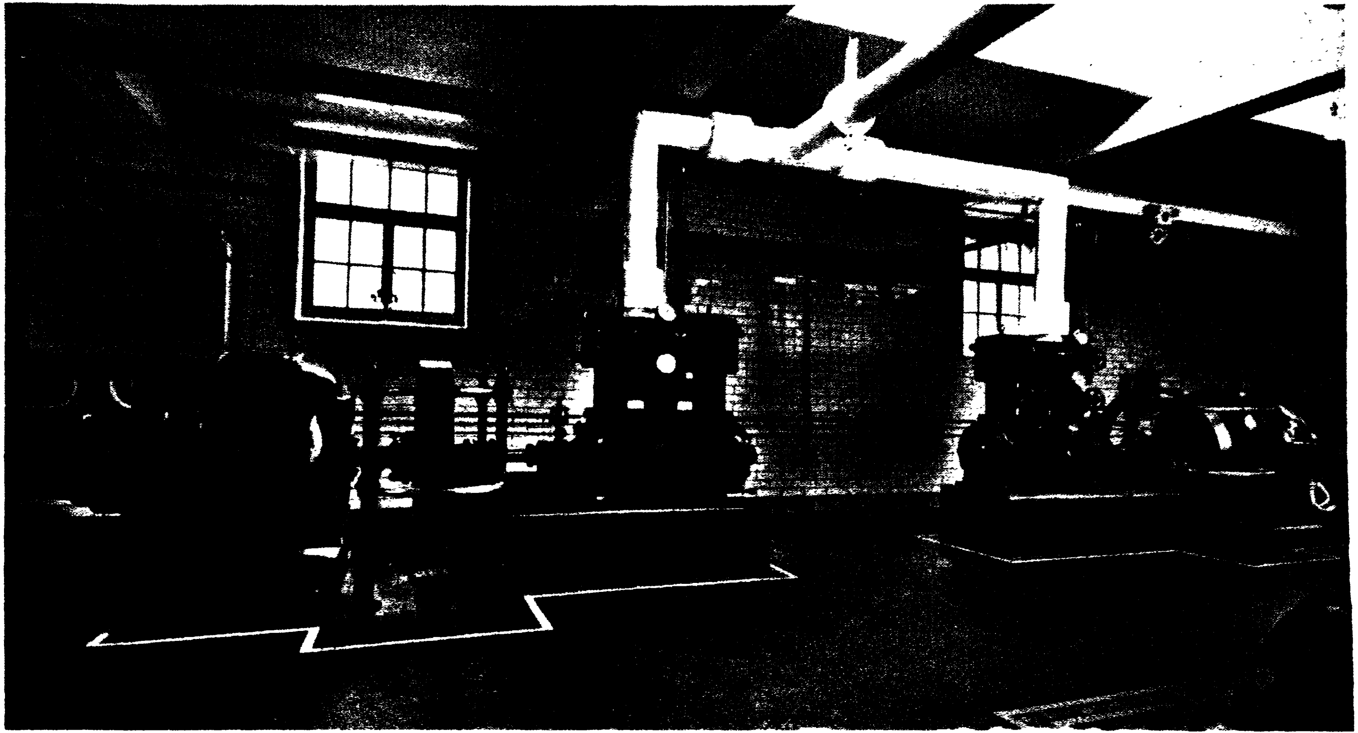
2. The continuous emulsification-cooling-kneading system. A preliminary mixing of fat blend, milk and ingredients such as salt, stabilisers, colour, etc., takes place in two vessels with agitators and means for controlling temperatures which alternately supply the pre-mix to a continuous high-speed emulsifying pump which passes the emulsion continuously to a refrigerated steel or stainless steel roller *via* a feeding trough attached to the roller. The solidified emulsion is scraped off and either conveyed by belt or falls directly into a hopper supplying one of the previously described closed continuous compressing and kneading machines, whence it emerges as a bar of plastic margarine ready for packing through plodding and shaping machines and automatic wrapping machines. Fig. Ma 5 shows a diagram of one of the best known systems of this type, the Gerstenberg Dia-cooler and Complector in which the working, compressing and kneading are done under vacuum to exclude incorporation of excessive air and at controlled temperatures to improve texture and plasticity. Other plants working on similar lines are the Atlas Lardin-Mycronisator system, the Silkeborg system and the Schröder system.

3. The continuous combined emulsifying-cooling-kneading system. The best known plant working under this system is the Margarine Votator, constructed by The Girdler Corporation Inc., Louisville, U.S.A. From supply vessels for the fat blend, containing also the fat-soluble ingredients, and milk, containing water-soluble ingredients, proportioning pumps deliver these components in the appropriate ratios of about 4 : 1 to a common inlet pipe for the Votator, a jacketed cylindrical vessel with a central rotor provided with specially designed scrapers. The fat-milk mixture passes through the narrow annular space between rotor and shell which is kept at about − 20° C. by evaporating ammonia in the jacket. The cooling effect and the high speed agitation by the scrapers solidifies, emulsifies and plasticises the mixture, causing a very fine dispersion of the milk in the fat. The high pressure of the pumps conveys the product in semi-solid form through the Votator and into another cylinder, the so-called B unit, where the margarine while firming up gradually is passed through one or more wire screens and finally emerges of suitable consistency for packing.



[*By courtesy of the Bristol Co-operative Society Ltd.*

FIG. MPD 8.—*A Well Arranged Boiler Room with Louvre Ventilation in the Ceiling.*



[*By courtesy of St. Cuthbert's Co-operative Association Ltd.*

FIG. MPD 9.—*A Well Planned Engine Room with Good Natural Lighting and Ventilation.*

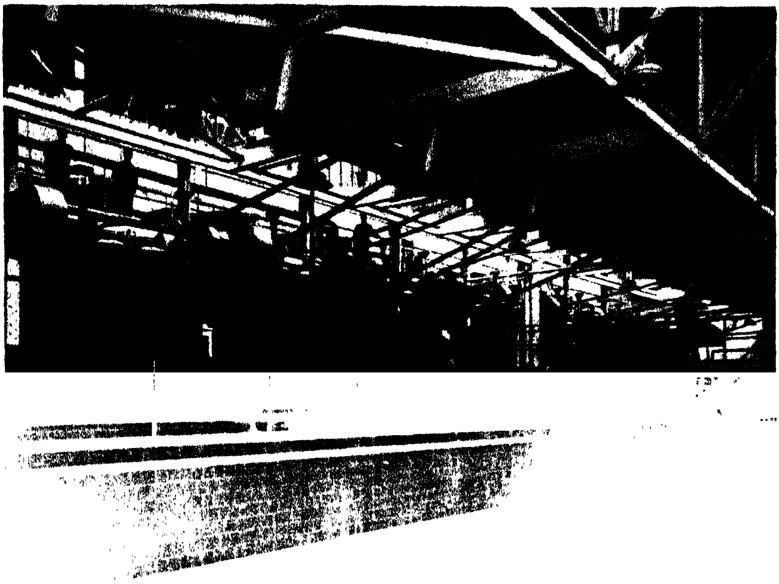


Fig. Ma 1.—*Battery of Eight Churns with Emulsion Pumps in front.*

[*Photos by courtesy of Van den Bergh & Jurgens Ltd.*

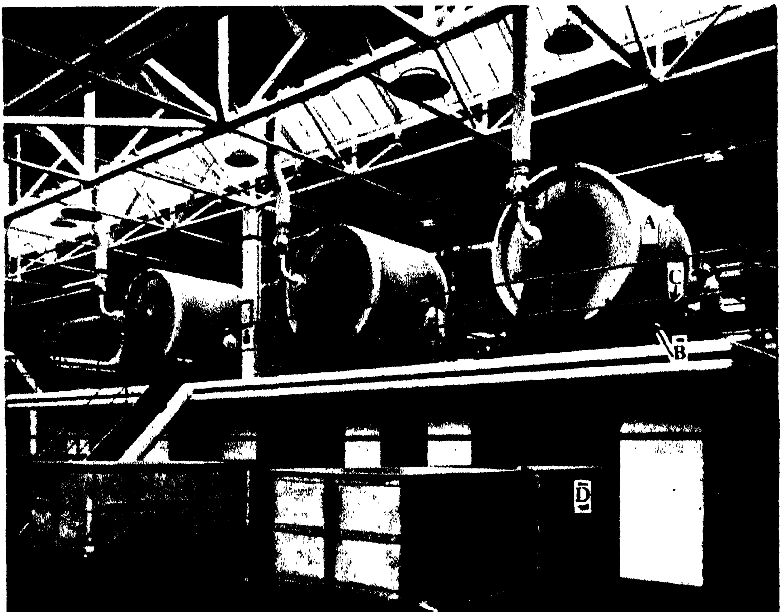


Fig. Ma 2.—(*A*) *Cooling Drums with Direct NH_3 Evaporation.* (*B*) *Feeding Trough with Feeding Roller.* (*C*) *Emulsion Pipe from Churns.* (*D*) *Containers for Collecting Solidified Emulsion.*

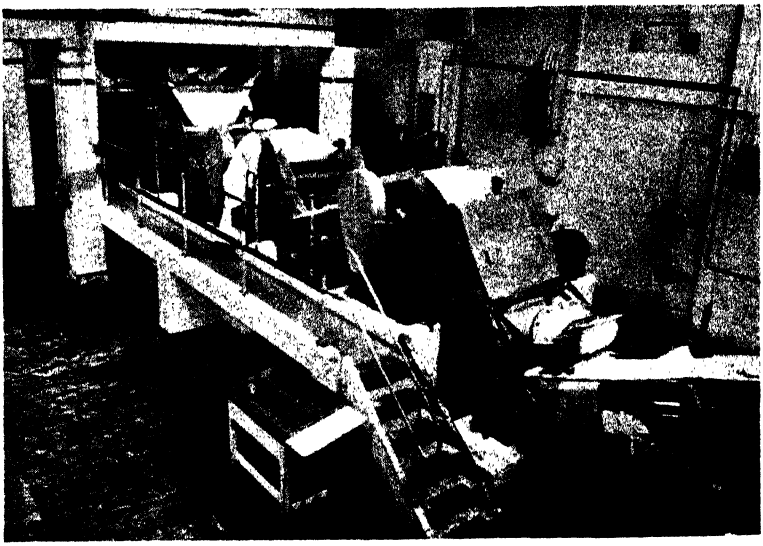
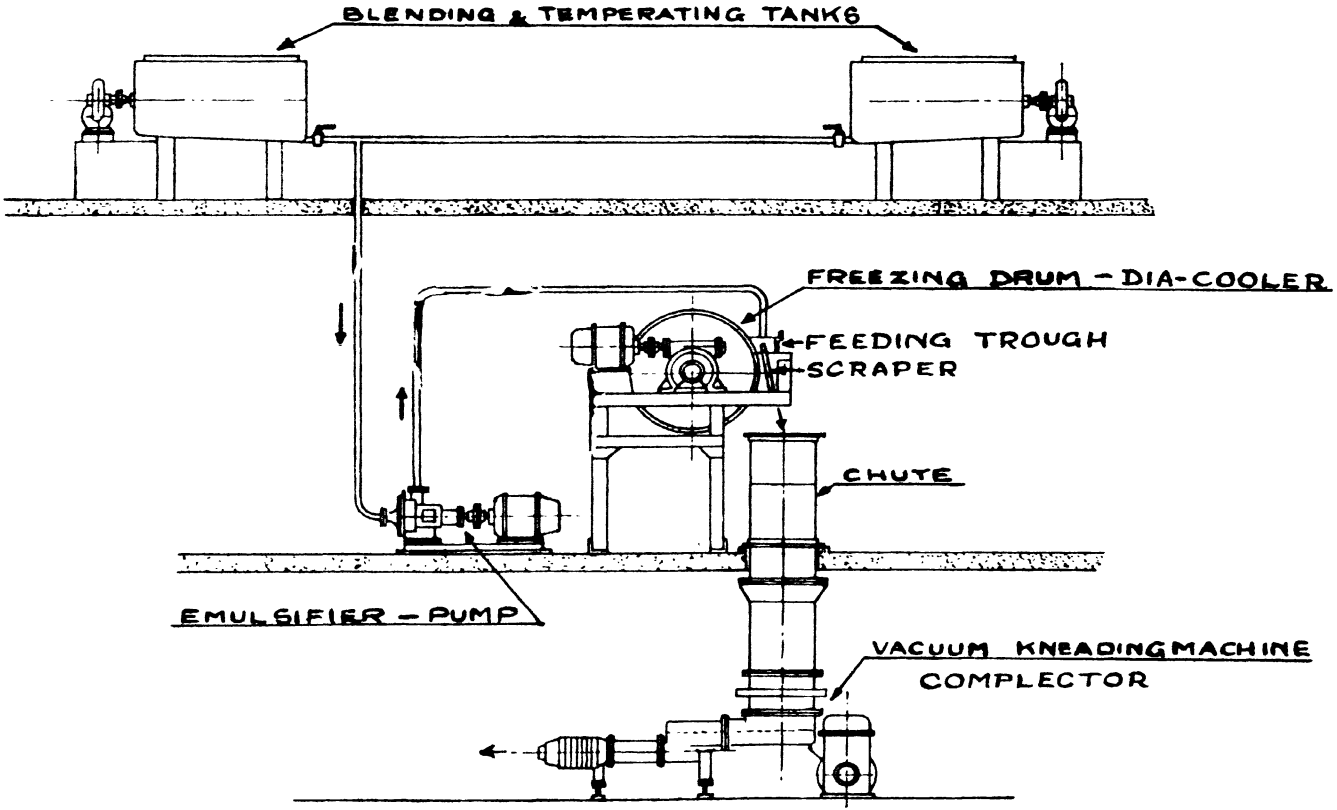


FIG. Ma 3.—*Roller with Three Pairs of Kneading Rollers, Extrusion Orifice and Cutter for Plasticised Margarine.*

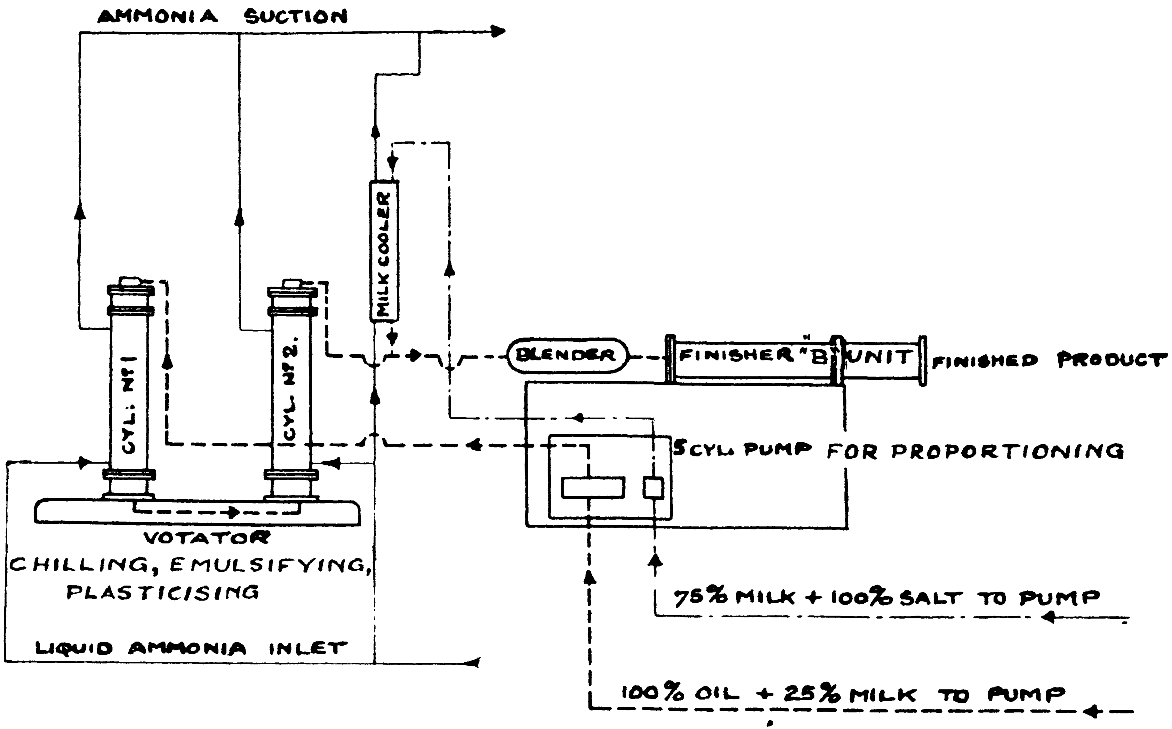
[*Photos by courtesy of Van den Bergh & Jurgens Ltd.*

FIG. Ma 4.—*Packing Room, showing Chutes for Supplying Empty Containers, and Automatic Moulding and Wrapping Plant for ½ lb. Packets.*



[*By courtesy of Gerstenberg and Aggar, Copenhagen.*

FIG. Ma 5.—*Diagram of Gerstenberg Dia-cooler and Complector plant.*


AMMONIA SUCTION
MILK COOLER
CYL: Nº 1
CYL. Nº 2.
BLENDER
FINISHER "B" UNIT
FINISHED PRODUCT
VOTATOR
CHILLING, EMULSIFYING, PLASTICISING
LIQUID AMMONIA INLET
5 CYL. PUMP FOR PROPORTIONING
75% MILK + 100% SALT TO PUMP
100% OIL + 25% MILK TO PUMP

[*By courtesy of The Girdler Corporation Inc., U.S.A.*

FIG. Ma 6.—*Flow sheet for Margarine Votator plant, made by The Girdler Corporation, U.S.A. In this diagram 25 per cent. of the milk is emulsified with the fat blend in the Votator, the remainder, after cooling, being added just before the blender. Other plants incorporate all the milk in the Votator, omitting the blender.*

Fig. Ma 6 shows a flow sheet for the Margarine Votator. The Johnson Votator and the Schröder Kombinator are similar plants.

The methods described are the most important used for the manufacture of household margarine. When required for special manufacturing purposes, such as bakery products, confectionery, biscuits, etc., modification in fat composition, the aqueous phase and ingredients are adapted to suit the particular object.

Owing to the close similarity between butter and margarine, also from the chemical and analytical point of view, it is compulsory in some countries to add for the sake of easy detection certain indicator substances, *e.g.* 0·2 to 0·5 per cent. starch or 2-5 per cent. sesame oil, the presence of which is easily detected.

The important question of the relative nutritive values of butter and margarine has been the subject of discussion and investigation from the time of the introduction of margarine. As regards calorific value and digestibility there is no practical difference. Butterfat, however, contains normally significant though varying amounts of vitamins A and D, whereas the fatty raw materials used in margarine are deficient in or devoid of these vitamins. During the last twenty years it has been possible to obtain vitamin concentrates from rich sources, or synthetically produced, in a form and quality suitable for incorporation in margarine, and the adoption of this method which in some countries, including Britain, is now compulsory has made this so-called vitamin margarine nutritionally equivalent to butter (Henry *et al.*, 1945 ; Smith, 1948).

In pre-war years the consumption of margarine in Britain was not as high as that of butter (1938 butter 519,000 tons, margarine 217,000 tons). During the recent war the rationing, and therefore the consumption, of margarine was at times 3 or 4 times that of butter, and exceeded an annual rate of 400,000 tons. *See* Butter ; Fat ; Butter, renovated ; Legal aspects.

Refs.: Clayton; Richmond; Clayton (1920) *Margarine*, London; Henry, Kon, Hilditch and Meara (1945), *JDR*, **14**, 45; Smith (1948), *BJN*, **2**, 190.

MARKETING. *See* Milk marketing.

Refs.: Roadhouse and Henderson; Min. Agric. (1936), " Report of Reorganisation Commission for Milk ", H.M.S.O.; Min. Agric. (1930), " Report on the Marketing of Dairy Produce in England and Wales ", Part I, Cheese; (1932), Part II, Butter and Cream, H.M.S.O.

MARQUARDT. *See* Solubility of milk powder.

MARSHALL RENNET TEST. *See* Rennet, standardisation.

MASS. Mass was defined by Newton as quantity of matter. In view of recent developments in physical theory, this definition is no longer strictly correct, and mass is better described as that property which defines the gravitational attractive force between bodies.

The point is that a cheese which weighs exactly 50 lb. in London would naturally weigh less if removed farther from the centre of the earth—say to the stratosphere. But the *amount* of the cheese would not be diminished thereby and, for everyday purposes we can best think of mass as that which defines what the weight of a body will be in any given gravitational field.

Weight (*q.v.*) is given by the force obtained by multiplying the mass by the gravitational acceleration. The scientific unit is the gram (p. 493). *See* Definitions.

MASSOL'S BACILLUS. An early name for *L. bulgaricus*. *See* Lactic acid bacteria.

MASTITIS. The term mastitis means, literally, " inflammation of the breast or *udder* ". Other names for this condition in cattle are *mammitis*, " garget ", " weed ", " chill in the udder ", " sore udder ", " felon quarter ", and " bad quarter ". Although the term mastitis includes all inflammatory conditions in the udder, modern usage has tended to limit its use to bacterial invasion of the udder by micro-organisms and especially by streptococci.

In some instances the condition is obvious to the milker. Such cases of acute mastitis may be due to certain streptococci (less common than the chronic type), staphylococci, coli, diphtheroids (" summer mastitis " is caused by a diphtheroid *C. pyogenes*), *B. tuberculosis*, actinomyces, and other types of micro-organisms. The chronic sub-clinical type is caused by *Str. agalactiae*, and the disease may persist throughout one or more lactations. Even the most expert person cannot detect these cases by inspection or examination of the animal. Clinical examination, for example, can detect only about 10 per cent. of infected cows, and the use of the indirect tests such as the bromcresol purple paper test from a third to a half. Further, such indirect tests are unsuitable for cows in late lactation and may give 10 per cent. or more false positives for cows in full milk.

It is unfortunate that this clinically undetectable type is contagious and that infected cows constitute a constant source of danger to uninfected animals. In most of these cases the producer and purchaser would never suspect the presence of mastitis in the udder or of streptococci in the milk without bacteriological examination.

Although often not so dramatic in its effect as some other diseases, mastitis is, nevertheless, indirectly the cause of much monetary loss to the industry.

Economic Aspects (*see* Table Ms I). (i) ***Milk yield.*** Mastitis is essentially the result of an invasion of the tissues of the mammary gland of the cow by pathogenic bacteria. As a result the milk-secreting cells are, to some extent, damaged or even destroyed, with the inevitable result that, according to the degree of infection and cell destruction, the yield of milk is lowered. Various figures have been quoted for the drop in yield as a result of mastitis, *e.g.* in Great Britain, 954 lb. per lactation for all the breeds considered, 10·8 per cent. of the yield for Ayrshires, and about 18 per cent. for Friesians (Minett and Martin, 1936). In America, a 22 per cent. loss in yield and a 24 per cent. loss in fat have been reported.

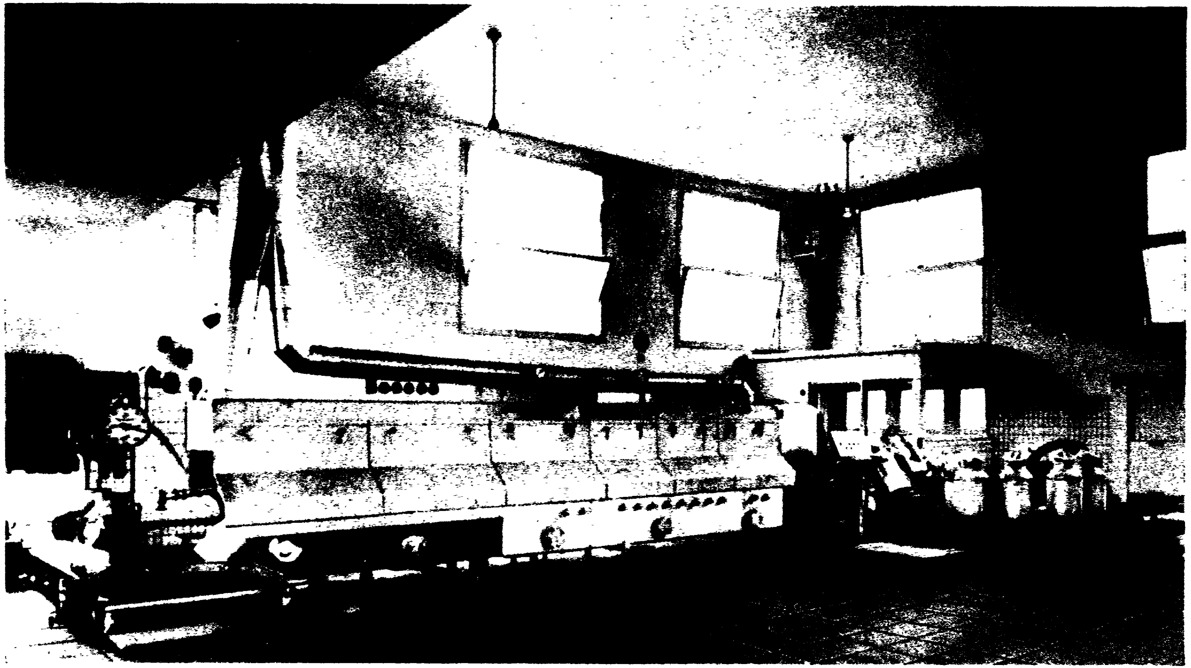
Milk records, when properly used, may occasionally be a valuable check on mastitis. A sudden drop in yield, otherwise unaccounted for, may indicate the onset of an attack. Where milk recording is not practised, these cases would probably not be detected until such clinical symptoms as fever and swelling (if they occurred) had become obvious.

(ii) ***Composition of the milk.*** The chemical composition or quality of milk is adversely affected by mastitis. The extent naturally varies with the degree of infection and type of organism. The constituents most affected are the lactose (or milk sugar) and chloride (or salt), the former falling and the latter rising to maintain the normal osmotic pressure. For this reason the freezing-point of milk unadulterated but low in solids-not-fat remains normal. In addition, the casein (the chief protein in milk) diminishes, and the globulin (normally only about 5 per cent. of the total protein) increases. This may serve as a chemical test for detecting mastitis (Rowland and Zein-el-Dine, 1938*a*). It is probable that many cases of " low solids-not-fat milk " are due to mastitis (Foot and Shattock, 1938, and Rowland and Zein-el-Dine, 1938*b*).

Mastitis milk has usually considerably less nutritive value, gal. for gal., than normal milk. In addition, it is frequently more alkaline (and so produces a purplish colour with bromcresol paper), has a low calcium content and, as a result of these two factors, clots less easily with rennet.

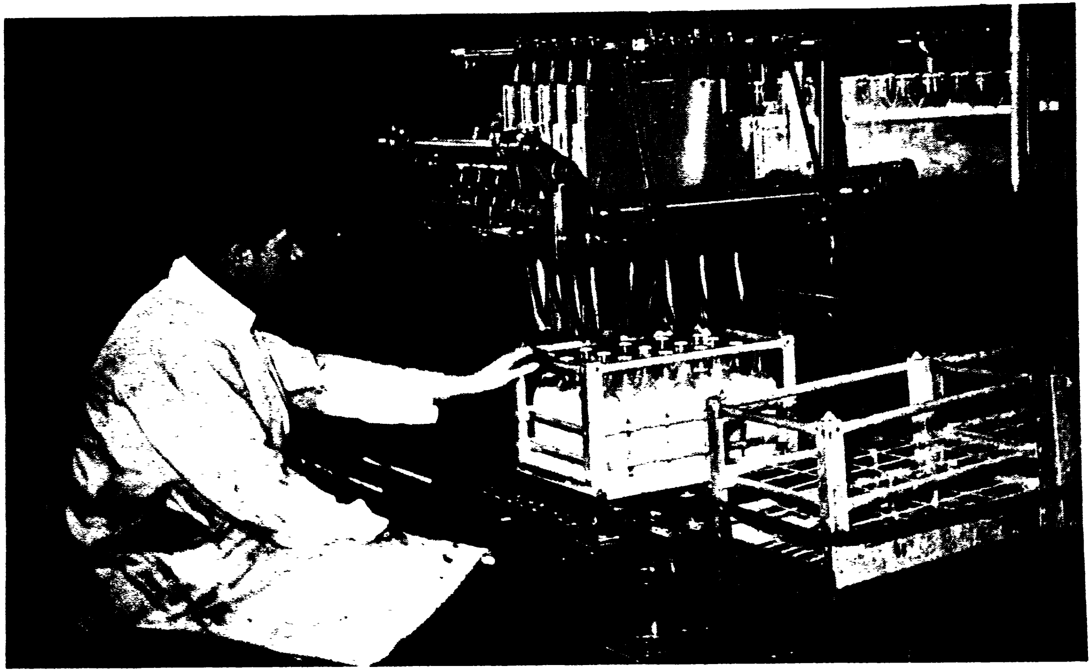
(iii) ***Bacterial count.*** After rejection of the foremilk it is found that the bacterial content of the milk taken from a healthy, mastitis-free cow is very low, nearly always less than 500 per ml. (28 ml. = 1 oz.), and very rarely greater than 2000.

Milk from a cow suffering from mastitis usually contains much greater numbers of bacteria, not only those causing the mastitis, but also cocci and other types (" secondary invaders ") likely to cause taints and lower the keeping quality of the milk.



[*By courtesy of Trollhätta Dairy and Fredriksons Verkstads, Vadstena, Sweden.*

FIG. MH 2.—*No. 3 FV Tipping Machine and Straight Line Can Washer.*



[*By courtesy of Standard Knapp.*

FIG. MH 3.—*A Mechanical Bottle-crating Machine. The bottles are mechanically conveyed to the assembly head (top), after automatic marshalling into the same number of rows as in the crate to be filled. The machine can fill* 800 *to* 900 *crates per hour.*

McClemont and Davis showed that 96 per cent. of mastitis-free cows had an " udder count " of less than 500 and none a count of over 2000. Of cows having infected udders, 30 per cent. had an udder count of over 2000. Such infection would be detectable with certainty only by repeated bacteriological examination. It is frequently stated that milk taken from young cows contains fewer bacteria than that taken from old cows. Older cows are, however, more liable to mastitis, so that it is necessary to distinguish between an increased count due to age and that due to an increased incidence of mastitis. These higher counts in older cows are, in fact, due to mastitis. Further, the bacteria in milk from infected udders increase rapidly in numbers on incubation; those in milk from non-infected udders do not increase rapidly for some considerable time. If early mid-milk samples are held in sterilised bottles at 37°, those from clean udders remain unchanged for a considerable time (3 to 7 days), while those from infected udders show marked changes in 1 to 3 days.

(iv) ***The methylene blue test.*** In view of the general application of the methylene blue test for grading milk and of the many statements concerning the effect of mastitis on the test which have been circulated, it may be of interest to quote the results obtained by McClemont and Davis. Of a large number of samples from individual cows, it was found that 23 per cent. of those from mastitis-infected cows failed to pass a certain standard, whereas only 5 per cent. of samples from uninfected cows failed the same standard.

It will be seen that milk from cows suffering from mastitis tends to have a shorter reduction time than milk from cows not suffering from the disease. The effect of mastitis in a herd on the behaviour of the bulk milk in this test will be obvious.

Now, mastitis streptococci do not reduce methylene blue, or do so with difficulty, as it is poisonous to them. It follows, therefore, that mastitis milk may contain large numbers of such streptococci, but take a long time to reduce methylene blue. This probably accounts for the observation that milk may be heavily infected with mastitis organisms, but give a long reduction time, *i.e.* pass as good quality milk. Another factor concerning this phenomenon may be changes in the chemical constitution of the milk. This may affect the reduction of the methylene blue, either by inhibiting bacterial growth (in rare cases) or by altering the chemical activities of the other bacteria. The reduction of methylene blue in milk is brought about by the chemical activity of these bacteria.

It seems probable, however, that in most cases mastitis decreases the reduction time by virtue of the higher number of other bacteria " secondary invaders " and leucocytes or white blood cells, which occur in large numbers in mastitis milk.

(v) ***Effects on cheesemaking*** (*see* Starters, p. 978). Mastitis has on many occasions been alleged to be the cause of faults in cheese, often without satisfactory evidence. The literature on this subject has been reviewed by Davis and Mattick (1936), who emphasise the fact that the term " mastitis ", loosely used, includes many types of the disease and abnormalities of the udder. These abnormal milks may be responsible for (1) slow starter, (2) poor-quality curd resulting in cheese of poor texture, and (3) off-taints and colour faults due to bacterial contamination.

Weak curd. If its chemical composition is appreciably affected, mastitis milk will produce a weak curd. Not only will slow starter result in retention of moisture through low acidity, but the calcium, casein, and acidity of the milk will be low (the extent varying with the degree of infection of the udder). These two constituents and the acidity are the most important factors in controlling the character of the curd. Low calcium, low casein, and low acidities result in weak-bodied curd, and it is impossible to make first-class cheese unless the milk is normal in these respects.

Off-taints. As already mentioned, milk from infected udders is frequently rich in bacteria, especially cocci, many of which attack the protein of the milk and produce foul-smelling substances. Such milk may thus easily lead to faulty cheese, especially if slow starter is encountered, owing to the weak acidities and high moisture content. The moisture in cheese is at a critical concentration for bacterial growth, so that a slight excess may easily allow fault-producing organisms to proliferate rapidly. Faults may thus reinforce one another.

Colour defects. Most colour faults in cheesemaking are due to aerobic (*i.e.* oxygen-requiring) micro-organisms. Slow starter, resulting in high moisture and poor texture, leads ultimately to cracking and the infiltration of air, thus permitting the pigment-forming organisms to grow. The interior of a good cheese contains too little oxygen to allow such types to flourish. The peculiar fault known as " red spot " in Cheddar cheese is due to an organism biochemically resembling the mastitis streptococcus which apparently lives a saprophytic existence in the udders of certain cows (p. 182).

(vi) ***Butter and cream.*** Many workers have reported that mastitis milk often imparts an objectionable flavour to cream, which is naturally also found in the butter. Butter from mastitis milk may also be very difficult to work (p. 133).

(vii) ***Condensed milk.*** If mastitis milk is concentrated it is found to be less stable to heat than normal milk. It also behaves curiously in that it is further destabilised at higher fore-warming temperatures and by the addition of calcium acetate. Mastitis milk also destabilises normal milk (p. 284).

(viii) ***Public health aspects.*** The common mastitis organisms (streptococci) are usually not pathogenic for human beings. Nevertheless, mastitis may on rare occasions be caused by a " human type " of streptococcus ; such milk would definitely be unsafe. Further, mastitis milk with large numbers of staphylococci may contain substances capable of causing severe illness in human beings. (*See* Diseases, human, and Food poisoning.)

Detection of Mastitis. Many tests for the detection of mastitis have been described. These may be classified as : (1) Those which demonstrate the presence of the causative organism in the milk, *e.g.* by plating in blood agar or other suitable medium ; (2) those which show changes in the udder, *e.g.* feeling for hardened tissue, and the catalase test : and (3) those which detect changes in the chemical composition of the milk, *e.g.* the chloride test and the casein number determination.

The first or direct method, performed at least twice, is the only really satisfactory one and can only be carried out by a veterinary surgeon or bacteriologist experienced in this particular work. There are, however, a number of simple indirect tests which will detect the worst cases or at least give an indication of the percentage infection of the herd. *Examination of bulk milk will detect only gross infection ; tests should therefore be carried out at least on single-cow samples and preferably on single-quarter samples.* The simple indirect tests to be described can easily be carried out on individual quarter samples by the milker, preferably at least once a fortnight.

(i) ***Bromcresol purple test.*** Hold four strips of bromcresol purple paper (which may be prepared by soaking filter paper in the saturated dye solution, or bought from chemists) fanwise between the finger and thumb of the left hand and let the milk from each quarter in turn fall upon a piece. If at the end of about 15 sec. any of the pieces is bright purple in colour, mastitis is probably present. The paper should not be examined in direct sunlight. This test is not suitable for late lactation cows as these may also give a positive test. The positive colour given by late lactation cows tends to be a strong navy blue colour rather than purple and is, as a rule, found in all four quarters. The ammonia from stale urine will also turn the test paper purple. The point to look for in a test of this nature is a marked difference between one or more quarters and the others. The eye soon becomes familiar with the normal colour—a dove grey.

(ii) ***Strip cup and dish tests.*** By drawing the fore milk on to a black sieve, fine particles of clotted milk may sometimes be seen when mastitis is present.

Alternatively, a shallow black dish may be used to catch a little milk. A positive bromcresol purple *and* strip cup or dish test may safely be taken as evidence of mastitis. Disinfectant should be added to the strip cup after use and the milk rejected.

(iii) ***Induration or hardening of the udder.*** Examination by hand of the udder of a freshly milked cow will sometimes permit diagnosis of mastitis by the detection of hardened tissue.

Eradication of Mastitis. (1) The first step to be taken by the owner is to have all cows in milk tested, preferably by bacteriological plating on blood agar. (The method of taking samples, etc., is described by Davis, McClemont and Rogers (1939, *JDR*, **10**, 60). The milk of each animal should be tested at least twice at intervals of not less than a week during each lactation, and preferably not before 3 weeks after calving. Diagnosis by the direct tests (*e.g.* strip cup, bromcresol purple, examination of udder, and catalase test) is less satisfactory. If it is impossible to have the herd tested bacteriologically, diagnosis may be made by systematic use of these simple tests. Before disposing of a valuable cow, however, the milk should be tested bacteriologically.

(2) The second step is the segregation of the herd or separation of all positive and suspected cows from the mastitis-free animals. *All bad cases, i.e. those animals continually excreting large numbers of mastitis organisms, should be treated or disposed of immediately.* The best procedure is to form two separate herds having separate sheds, utensils, and milkers. Frequently this is impracticable, and if so the infected cows should be placed in separate standings at one end or in one row of the shed. These should have their own milkers and utensils, which should not be used for the clean animals.

(3) In both clean and infected herds or groups, cows should be arranged in order of number of calves so that the heifers are milked first and the oldest cows last.

(4) All incoming heifers and cows should be tested. Only those animals giving a negative result on two tests should be accepted.

(5) All animals should be tested every lactation. A complete test of the milking herd every 6 months is the simplest way of ensuring this.

(6) Good herd management is essential, especially in regard to milking, *e.g.* regular milking, efficient stripping and avoidance of overstocking.

Necessary Precautions. (1) Cows should be milked in order of age, *i.e.* heifers first and oldest cows last.

(2) Hands should be washed before milking each cow.

(3) Udders should be washed down in a weak disinfectant (*see* Chlorine), using sterile udder-cloths.

(4) Milkers handling infected cows should not milk the mastitis-free animals.

(5) In general, carry out the directions laid down in *Modern Milk Production* (Ministry Bulletin No. 52).

If cows are tested regularly over a period, it will be found that a few appear to recover from the disease, *i.e.* mastitis organisms can no longer be recovered from their milk. It is dangerous to transfer such animals to a mastitis-free herd.

Some infections may be very slight and the effect on milk quality barely detectable, so that it may be doubted whether the condition can be termed " mastitis " in the ordinary sense of the word.

Nevertheless, any animal excreting the organism in the milk is a potential source of infection and so, in any eradication scheme, should be regarded as a " positive ". Animals not severely infected and which are otherwise in good health and giving a high yield of apparently good quality milk may be kept in the " positive herd " until a convenient opportunity for their disposal occurs. It is obviously not practicable to dispose of all positive cases at once.

TABLE Ms I

PROPERTIES OF MILK AFFECTED BY MASTITIS

Property	*Normal limit*	*Effect of mastitis*	*Test*
Bacteriological aspect of aseptically taken udder sample :			
Str. agalactiae count	0 (?)	Increased	Plate count on differential medium, etc.
Staphylococci count	(?)	Increased	Plate count on differential medium, etc.
Count of other mastitis organisms (Minett Groups II and III, " bovine pyogenes ", etc.)	0 (?)	Increased	Plate count on differential medium, etc.
Total bacterial count	300 per ml.	Increased	Plate count on milk agar
Physiological :			
Cell count	50,000 per ml. (varies)	Increased	(i) Microscopic (ii) Catalase (iii) Sediment
Chemical :			
Lactose	4·8 per cent.	Decreased	Analysis
Sodium chloride	0·115 per cent.	Increased	Analysis
Casein	78 per cent. (of total N)	Decreased	Analysis
Calcium	0·12 per cent.	Decreased	Analysis
" Globulin "	5 per cent. (of total N)	Increased	Analysis
Total protein	—	Not usually affected	—
Titratable acidity	0·14 to 0·17	Decreased	Titration
*p*H	6·5 to 6·65	Increased	—
Solids-not-fat	9·1 per cent. (Jersey and Guernsey)	Decreased	—
	8·8 per cent. (Shorthorn)	—	—
	8·5 per cent. (Friesian)	—	—
Clotting with rennet	—	Retarded	—

No certain method of curing mastitis is known, but promising results are now being obtained with sulphanilamide and penicillin. Reports are made of the successful use of various antiseptics, dyes, and preparations of silver albuminate and other substances under trade names. The economic importance of mastitis to the dairy industry is undoubtedly comparable to that of tuberculosis and contagious abortion, although its effect may not be so evident to the eye, and a national scheme for its reduction to insignificant proportions is highly desirable.

The now widespread use of penicillin has led to a reduction of the over-all incidence of mastitis in this country from about 35 to 15 per cent. or less. Treatment should only be given under the supervision of a veterinary surgeon and milk from a cow under treatment should be withheld from the market until three meals after the last treatment. Such milk, by its effect on cheese starter, can cause havoc in cheesemaking (*see* Cheese ; Starters). *See* Abnormal milk ; Coliform mastitis ; Diseases of dairy cattle.

Refs. : Jacob (1947), " Investigations on Streptococcal Mastitis and the Streptococci ", Reading Univ., Ph.D. thesis ; Little and Plastridge (Editors) (1946), *Bovine Mastitis*, London ; Merchant and Packer (1952), *Handbook for the Aetiology, Diagnosis and Control of Infectious Bovine Mastitis*, Minneapolis ; Thompson (1945), " A Study of Certain Biological Factors Influencing the Nutritive Value of Milk with Special Reference to Mastitis, etc.", Reading Univ., Ph.D. thesis ; Munch-Petersen (1938), *Bovine Mastitis. Survey of the Literature to the End of* 1935, London ; Rosell (1933), *La Mammite Streptococcique de la Vache*, Quebec ; Berger and Francis (1951), *VR*, **63**, 283, 305 ; Wilson and Slavin (1950), *JCPT*, **60**, 230 ; Chodkowski (1949), *JCPT*, **59**, 275 ; Stableforth (1950), *VR*, **62**, 219 ; Weitz (1949), *VR*, **61**, 123 (summer mastitis) ; Stableforth *et al.* (1949), *VR*, **61**, 357 ; Buxton (1949), *Brit. Vet. J.*, **105**, 107 (Group C strep.) ; Francis (1948), *VR*, **60**, 253 ; Neave *et al.* (1952), *JDR*, **19**, 14 ; McLeod and Wilson (1951), *JDR*, **18**, 235 (yield) ; Dodd and Neave (1951), *JDR*, **18**, 240 (machine milking rate) ; Crossman *et al.* (1950), *JDR*, **17**, 128 (yield of individual quarters) ; Neave *et al.* (1950), *JDR*, **17**, 37 (dry period), Ineson and Cunningham (1949), *JDR*, **16**, 139 (season and lactation) ; Seelemann (1947), *M*, **2**, 237, 249 ; Neave *et al.* (1949), *SAB*, No. 1, 34 (testing method) ; Mattick *et al.* (1941), *JDR*, **12**, 139 (detection of *Str. agalactiae*), Harrison (1941), *JDR*, **12**, 18 (transmission of *Str. agalactiae*) ; Johns *et al.* (1940), *JDR*, **11**, 298 (effect on cheese) ; Shattock and Mattick (1940), *JDR*, **11**, 311 (staphylococcus mastitis) ; Rowland and Zein-el-Dine (1938), *JDR*, **9**, 174 (" casein number "), 182 (effect on SNF) ; (1939), *JDR*, **10**, 108 (indirect tests) ; (1939), *JDR*, **10**, 267 (" casein number ") ; Davis *et al.* (1939), *JDR*, **10**, 59 (routine diagnosis), 74 (comparison of indirect tests), 81 (" udder counts "), 88 (effect on MB test), 94 (effect on cheese), 104 (general) ; Foot and Shattock (1938), *JDR*, **9**, 166 (low SNF) ; Minett and Martin (1936), *JDR*, **7**, 122 ; Davis and Mattick (1936), *AP*, **13**, 126.

MATERIALS. *See* Bottles (for glass) ; Metals ; Packaging ; Pipelines ; and various dairy products and metals.

Refs. : Smith (1946), *Materials of To-morrow*, London ; Harper (1951), *DI*, **16**, 1163.

" MAY TROUBLES." This phrase is used colloquially for the troubles peculiar to May and sometimes April in cheesemaking farms and manufacturing creameries. The troubles are chemical and bacteriological in origin and are probably due to : (i) cows going out to grass with the consequent change in chemical composition of the milk and looseness in the dung leading to increased contamination by coli and other faecal organisms ; (ii) increased yields ; (iii) warmer weather ; (iv) the fact that there is always a necessary " settling down " period in any type of manufacture ; (v) changes in acid-base and salt balances ; (vi) colostrum. This aspect is of special significance in condensing and evaporating.

MAZOUM, MAZUN, MATZOON. A fermented milk of the *yoghurt* type in Armenia.

MEASUREMENT OF MILK. *Farmers' supplies.* (i) Milk may be bought legally only by the Imperial gal., although actually the milk may be weighed by the buyer. Two systems are in use in this country : (*a*) the farmer records his milk to the nearest quart; (*b*) the buyer weighs the milk to the nearest lb. and the total for a given period is converted to gal. by the official factor 10·32, *i.e.* for every 10·32 lb. the farmer is credited with 1 gal.

In some cases there is a deep distrust by farmers of the weighing method but obviously it is the most accurate, provided the scales are accurate and properly used and a correction for drainings added.

(ii) *In tankers.* A dipstick calibrated in ft. and in. from the rim of the manhole is used and the volume of milk read off from a calibration chart. It is essential for the tanker to be on a level keel.

(iii) *In storage tanks.* Various methods are in use such as: (*a*) visible pipe level; (*b*) graduation marks; (*c*) pressure indicators. Modern instrumentation has led to the introduction of liquid level indicators which can be used for all types of tanks. They usually consist of one or two electrodes and when the milk touches one or both a circuit is completed and a light shines or bell rings. The levels may be selected at will or, by sliding the electrode(s) down to the milk level, a fairly accurate measurement of the milk volume is obtained.

(iv) *In churns.* By graduations on the side.

(v) *In bottles.* The bottle is used as a measure " by custom ", although this is not strictly legal. Bottles are usually designed to give the required measure when filled to ⅜ in. from the top. A greater space has to be allowed in sterilised milk bottles and the filling level is usually about 2⅝ in. from the top. The older types of fillers measured out the volume of milk but the modern vacuum types fill to a certain level. *See* Bottle-filling; Costings; Legal aspects; Management of creameries, of pasteurising depots; Wastage.

Ref.: Wilcox (1948), *JSDT*, **1**, 189.

MECHANICAL DESTRUCTION OF BACTERIA. It is possible to kill bacteria although not all the cells present, by mechanical means, *e.g.* by violent agitation, shaking with glass beads, etc. *See* Pasteurisation, alternatives to.

Ref.: King and Alexander (1948), *JGM*, **2**, 315.

MECHANICAL EQUIVALENT OF HEAT. 1 B.Th.U. ≡ 772 ft. lb.; 1 calorie ≡ 4·185 joules.

MECHANICAL HANDLING IN THE DAIRY INDUSTRY. Mechanical handling of goods and processes is a particular feature of modern industry, and in the milk industry increasing attention is being given to this method of rationalising dairy work. It could be said that mechanical handling was introduced into dairying when herdsmen first began to use the yoke over the shoulders from which were suspended two pails of milk. The object in that case was to render the work easier and that same principle still applies today.

Broadly speaking, there are two main reasons for the extension of mechanical handling in dairies, (i) the economic aspect of increasing productivity per man-hour, and (ii) the ergonomic aspect of better utilisation of the restricted labour force available.

The high expense of labour and meagre trading margins have induced energetic efforts to reduce the cost of the work performed, while the shortage of staff has necessitated the removal of the more burdensome tasks in order to render a wider range of workers capable of carrying out the work concerned. Mechanical handling is a convenient and effective approach to these objectives, and is being increasingly exploited throughout the dairy industry today.

Principles of Mechanical Handling in Dairies. Milk, because of its liquid and highly perishable nature, necessitates bulk processing, and accordingly the basic principles of mechanical handling in such circumstances lead naturally to the establishment of a belt or conveyor system of handling. In dairies the development and application have been in two main stages: first, to design machines which provide the main flow line, *e.g.* bottle-washing, filling and capping machines, and now, more recently, to deal with ancillary processes to and from this flow line in a rationalistic and mechanical manner.

As is to be expected, that part of the industry concerned with processing and packaging for the liquid market has been much to the fore in adopting mechanical handling, although milk product manufacturers are energetically pursuing the same course. An indication of this is shown by the wide interest in continuous butter-making machinery. On the other hand, dairies manufacturing evaporated and condensed milk and milk powder, etc., have practised mechanical handling of a very high order for a long time.

The main principle is to examine each job in turn, breaking it down into its component parts with a view to carrying out the various movements by mechanical processes. This is well demonstrated, as will be seen later, in the application of mechanical handling to the work on the platforms for the reception of milk in cans from the farms. Furthermore, one must not be afraid of adopting a mechanical innovation, nor be deterred from attempting to apply mechanical processes by reason of the unusual method of carrying out the work. It will be seen, too, that for maximum results mechanisation should be aimed primarily at those jobs where the number of workers can be reduced, rather than attempting to apply mechanical methods where the same operators will still be required, as, for example, loading a retail vehicle. Such aspects constitute the secondary approach of mechanisation.

Objects of Mechanisation. The objects of the development of mechanical handling and mechanisation in dairies are such as to render the work very much more acceptable to workers in dairies—particularly in dairies devoted to milk processing and bottling. The chief objects are to make the work less arduous, and also achieve, where possible, an acceleration of throughput—these two objectives being accompanied by the search for reduced operating costs.

The methods of achieving these objectives are to eliminate all avoidable handling, and in other cases to reduce handling to the practical and most economic minimum. The methods adopted are to make the maximum use of the flow of milk in pipes, of conveyors for handling bottles, cans, crates, etc., and of the application of mechanisms using the most modern and approved mechanical contrivances, with the assistance of pneumatic, hydraulic, and electronic devices. So far as mechanical handling of cans and crates is concerned, the object is to eradicate the costly practice of placing them on the floor.

It is essential that the adoption of mechanical handling be " balanced " throughout the different sections of the work in the dairy. A certain basic number of staff will be necessary, even although they are primarily concerned with the supervision of machines. For instance, unless the balance is carefully preserved, one can easily visualise mechanical processing requiring a very small number of workers, and after processing is complete the number of workers available being insufficient for the job of plant cleaning. The ultimate balance must then be kept well in mind when embarking upon progressive mechanisation.

The limits of this article do not allow a detailed account of the various aspects of mechanical handling throughout the industry but, as examples, indications can be given of what has already been achieved and which lines of development are being pursued in this matter, particularly in certain branches.

Milk Reception. It has been shown (Inglis, 1951) that the milk produced in England and Wales comes from 160,000 farms, and is delivered daily to over 7000 separate destinations by some 10,000 vehicles. It has also been suggested (Ritchie, 1951) that the annual 1360 million gal. from wholesale producers is delivered in approximately 500,000 cans daily to town and country depots. This, then, is an obvious field for the application of mechanical handling, and gives a good opportunity for successful results. In former times, it was the custom to unload the cans of milk from horse-drawn or motor collection lorries and roll the cans along a specially constructed platform to an inspection and tipping point at which the cans were emptied (the quantity of the contents having been determined by volume) or where the milk was weighed. The empty cans were then manhandled to the washing and sterilising point, and thence back to the collection lorry. It will be seen that the passage of the cans on the reception deck is roughly in a circle, and in a mechanised layout the arrangement of machines for carrying out these different jobs is referred to as a "circuit". The conveyor or belt system is a logical means of effecting a circuit and this has been the basic principle followed in mechanising milk reception. A simple circuit for the reception of one grade of milk is set out diagrammatically in Fig. MH 1.

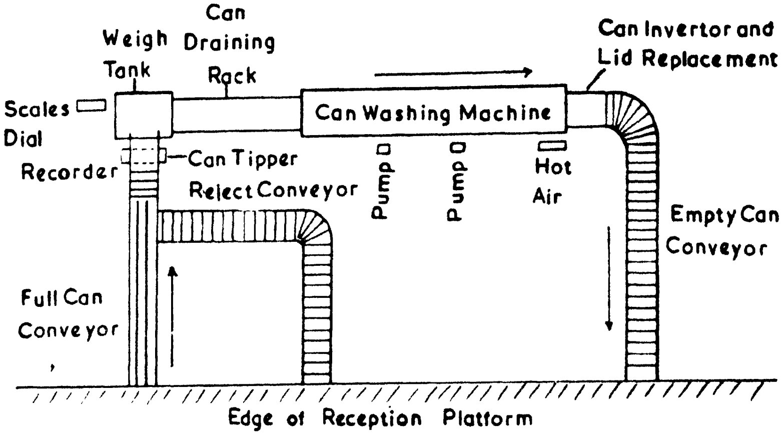


FIG. MH 1.—*A Simple Mechanised Circuit for the Reception of Ex-farm Milk, showing the Various Component Parts.*

Nowadays the cans can be unloaded from the collection lorries direct on to a conveyor, where they are inspected and proceed to a manually-assisted tipping point, doubtful cans being by-passed to a branch line for testing. After emptying, the contents are weighed, and the cans, now inverted, pass with their lids over a draining rack which is mechanically coupled to the automatic can washer, after passing through which the clean and sterile cans are turned upright, the lids replaced entirely mechanically and then proceed on the outgoing conveyor back to the collection lorry.

More recently, an automatic can tipping device (Ritchie, 1951) has been developed in Sweden, which eliminates manually-assisted tipping, and only the weight recorder is required at this point (Fig. MH 2). Here again development has produced the print-weigh machine whereby the scales activates a printing machine which issues a card for return to the producer with the weight of his consignment printed on it (Procter, 1948).

In Holland (Ritchie, 1951), an automatic sampling device has been produced which mechanically samples each consignment and fills a correspondingly marked bottle for subsequent chemical test to assist the payment for milk on a fat content basis.

The various aspects of the work involved in milk reception have been mechanised progressively, and striking improvements in the gallonage handled per man-hour have been achieved as follows (Ritchie, 1951):

Hand rolling and tipping	500 gal. per man-hour
Power conveyors and manually-assisted tipping .	1500 gal. per man-hour
Fully automatic reception	3000 gal. per man-hour

Handling of the Milk. In modern days, the system almost invariably applied is that of pumping milk along pipes to the pasteurising or sterilising plant, and in the case of pasteurised milk the processed and brine-cooled milk is thus conveyed to the bottle-filling machines where the bottles are filled and sealed in automatically operated machinery (Graham-Enock, 1951). The bottles then pass by conveyor to a point at which they are placed in crates. This crating operation has been mechanised for a considerable number of years in the breweries and soft-drink factories of North America, and is also being applied in some of the more advanced dairies in this country, where it has been in operation since about 1948 (Fig. MH 3). The crates of bottles are then conveyed mechanically to a point at which stacking takes place on stillages, and this may be done either mechanically or manually. The mechanical stacking of crates is an excellent example of lightening a really burdensome task when it is remembered that a crate of 20 pint bottles of milk can weigh up to 66 lb. and with the older method the worker had to raise this weight manually up to shoulder-height and sometimes higher. The stillages of piles of crates, usually 20 or 24 in number, are conveyed either by a hand-lifting hydraulic truck to a cold room if the operation has not been effected there, or to a platform, whence they are despatched to a distributing depot (Fig. MH 4). The operation of loading on to lorries can be effected by the use of fork lift trucks which lift the stillages of crates of bottled milk from the platform, and the trucks then move and lower the stillages of crates into the correct position on the lorry bodies (Fig. MH 5). This again is an operation which eliminates a great deal of hard work from dairies and is also effected very quickly and economically. Other systems have been designed for dealing with crates of milk in a similar manner, and one can see examples of batches of crates of bottled milk being held in metal frameworks and slung on to the lorry bodies from the platform deck by means of overhead rails and electric cranes or by manually-operated cranes. As a general comment it can be pointed out that the handlers of liquid milk in these days just cannot afford to put crates of milk on the floor and some quicker and cheaper way of handling has to be provided.

Pallets. To achieve efficient mechanical handling of goods, it is essential that the best type of pallet, stillage, or platform for the particular purpose concerned should be used.

For the liquid milk industry, the choice of wood is unsuitable and open-frame steel stillages (Fig. MH 6) are commonly used. The type is such that when not in use the stillages will nest safely one above another to a considerable height, thus effecting a considerable saving of space.

With the common type two-way or four-way entry pallet, the question of nesting does not arise, as no economy is obtained. When, however, pallets of the box or cage type are used, the storage of empty cage pallets can be an embarrassment unless the sides can be dropped to a horizontal position, or unless a tapered cage pallet is used, of such a type that they can nest one within another.

The size and shape of pallet must be based upon the type of crate which is used for the milk bottles and, logically, the distributive vehicles as well as heavy lorries for the transport of bottle supplies to distributive depots should have bodies of the size and shape most suitable for accommodating the load without any wastage of floor space.

The Washing of Bottles. Empty milk bottles brought back from the customer to the dairy are normally in crates, and these are conveyed to a point at which the bottles are removed for the purpose of washing. This operation of uncrating bottles has always been effected by hand, but at the time of writing there are numerous dairies in various parts of the world where the operation has now been mechanised, either fully or on a manually-controlled basis (Fig. MH 7). In such instances the bottles are deposited on a live conveyor, they are unscrambled on to a single line of conveyor belt, and conducted to the load end of the washer where automatic mechanism inserts the bottles into the pockets of the washing machine. After washing has been completed (and this is a very important aspect of mechanisation in dairies), the bottles are discharged automatically and conveyed by slat conveyor chain to the filling machine which has already been referred to.

Conveyors. The establishment of a belt system and the increasing use of conveyors generally, have played the greatest part in the application of mechanical handling to dairy work. Basically, the bottle-washing machines and can-washing machines of the present day are merely examples in which conveyors of one type or another are passed through machines in such a way that the bottles or cans receive the necessary treatments to obtain and maintain both physical and bacteriological cleanliness.

There are many and varied types of conveyor to be seen in use, some chosen for a particular purpose and others apparently merely reflecting the individuality of the user or the conveyor manufacturer. Bottles are normally carried by slat conveyors and very ingenious devices are attached, where necessary, to reduce unorderly lots of bottles down to a single line, increase a single line into multiple lines (usually multiples of two), space the bottles out for subsequent entry to other machines, and act as timing stops which allow only a given number of bottles to pass at each operation. Churns and crates, whether full or empty, are usually transported by multi-plane articulating link conveyors which are very flexible in operation. Recent trends, however, are towards simpler designs. The American " Rex " type slat-band conveyor for bottles has a clean design and facilitates more economic fabrication. In Europe different conveyors have been seen which are simply chains; in one case the vertical links have an overlapping extension, and in another example merely a chain made of ellipsoidal links, but having placed at regular intervals throughout its length circular links which move the cans or crates, according to its application. These are proving very efficient.

Where the elevation exceeds a slope of 1 in 24, it is advisable to use a positive-carry type of conveyor. Here again a wide diversity of types is seen. For descents and inclines gravity conveyors, either in the form of straight or spiral skids or slides, and the ubiquitous roller conveyors are used. It should be emphasised that it is more expensive and unnecessary to use power-driven conveyors where gravity conveyors can be employed. Roller and other gravity types of conveyors can be very efficient, and their use wherever possible is in complete accordance with the principles of mechanical handling, a fact which does not appear to be fully realised.

Cheese-making. This is an aspect which is receiving a great deal of attention at the present time for a number of reasons, but perhaps chiefly owing to the shortage of labour. It is difficult in many countries to find staff who will put up with the heavy work of stirring the milk, handling the curd, and also turn the cheeses as required. Recent advances are of such an order that some 500 or 1000 gal. of milk in cheese vats are now gently agitated by mechanical means instead of by manual operation. Now, however, various other mechanical aids are being used in cheese-making dairies. The development of the cheese trommel (Sharkey, 1949) is a remarkable innovation, not only for its ingenuity, but also for its efficiency and considerable saving of labour. Examples can be seen where the curd itself is conveyed short distances by conveyor to the grinding mill. At other stages after pressing, the cheese may be conveyed to the ripening room, where even the shelves can be turned; thus the daily turning of cheese can be done with much less labour than previously, and the handling of the individual cheese entirely eliminated. Other aspects can be seen whereby treatment with brine and waxing of the cheese can be carried out entirely mechanically. These various points not only cheapen the making of cheese, but make the work much less arduous than formerly.

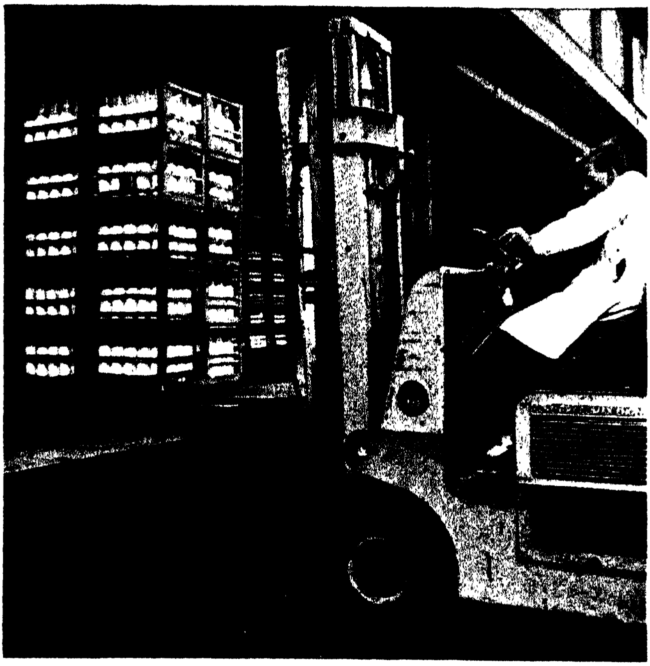


FIG. MH 4.—*The Fork Lift Truck has almost universal application, and in most cases the particular advantage of being capable of handling existing equipment. Here a Fork Truck is about to lift a stillage with twenty crates (400 bottles) from a loading deck.*

[*Photos by courtesy of B.C.S. Dairy.*

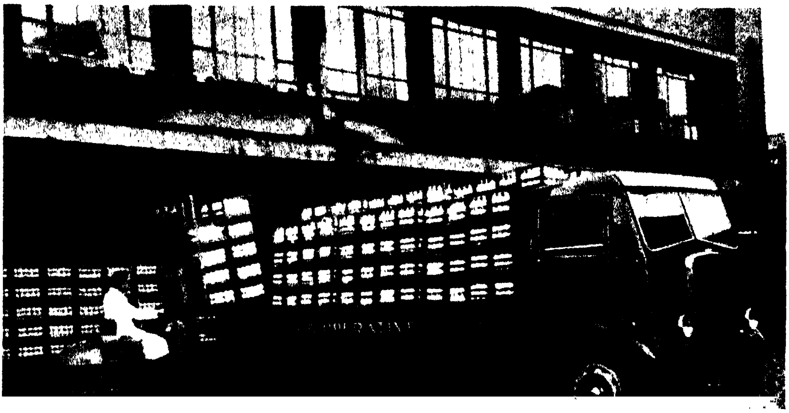
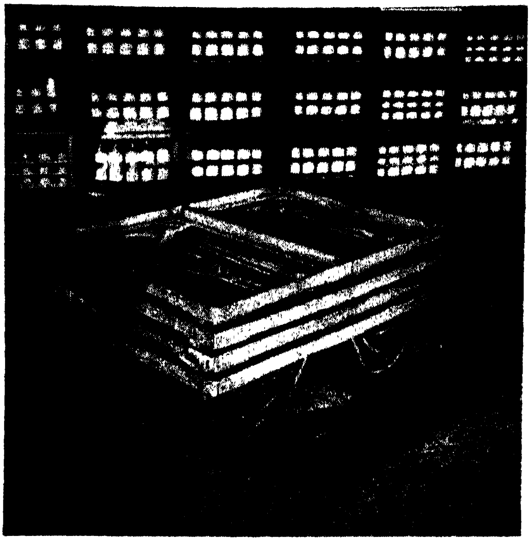
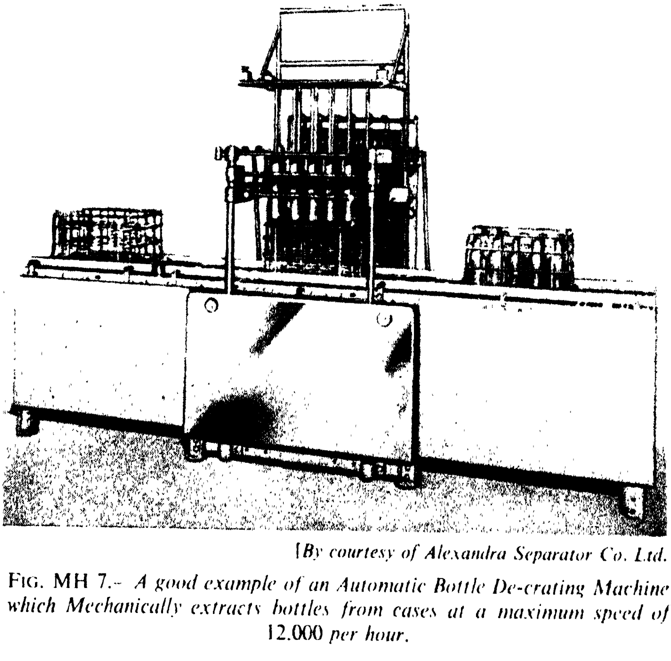


FIG. MH 5.—*The Fork Truck is Shown Depositing the Loaded Stillage on to a 7-ton Lorry for Despatch.*



[*By courtesy of B.C.S. Dairy.*

FIG. MH 6.—*Open Frame Galvanised Steel Stillages can Nest One Above Another to save space. In the background these are shown with cases of bottled milk stacked in columns of four* (2 × 2).



[*By courtesy of Alexandra Separator Co. Ltd.*

FIG. MH 7.—*A good example of an Automatic Bottle De-crating Machine which Mechanically extracts bottles from cases at a maximum speed of* 12.000 *per hour.*

Condensing Factories. The manufacture and handling of condensed and evaporated milk have been highly mechanised for many years, and it is interesting to see how the cans are made and conveyed mechanically by the most ingenious methods from one operation to the next, how they are then conveyed to the point at which filling takes place, how the seaming or other means of fastening is practised, and how the cans are conveyed still mechanically to the point at which they are fed (for evaporated milk) into the steriliser. Here again one has the problem of packaging the tins of processed milk into cases, and machines for this purpose can be seen which are very similar to the bottle-crating machines in the liquid milk market dairies. These methods of skilful mechanisation have made it possible to manufacture evaporated and condensed milk at the most competitive rates.

Other Branches of the Industry. It is, of course, possible to give many more instances of successful mechanisation within the dairy trade. The manufacture and handling of milk powder are very well mechanised today, and the continuous butter-making machine has made rapid progress. The ancillary processes in the butter industry, such as packaging, wrapping, printing, and weighing, have already been largely mechanised, and the machines are most ingenious and efficient. Continuous ice-cream-making plant is now also very widely adopted, and has made significant contributions to the development and technique involved with the manufacture of this product.

Continuous freezers, multi-colour and flavour extruders, continuous hardening tunnels, mechanical cutters for brickettes, chocolate-enrobing units which control the thickness of coverture down to a semi-translucent film of chocolate some thousandth part of an inch thick, and refrigerated cooling tables are some of the examples which plant manufacturers have ingeniously designed for this increasingly important branch of the industry.

The Effect on the Design of Dairies. Mechanical handling, in addition to the obvious objectives which it is designed to attain, has had other influences on the dairy industry.

Formerly, it was usual to erect substantial buildings for milk processing and the dairy industry in general. Nowadays different circumstances have led to increasing attention being paid to alternative and cheaper forms of construction for dairy buildings. Mechanical handling of the work has played a significant part in evolving this more modern, light type of structure.

By the use of conveyors and lifting devices, it will be seen that loading platforms and reception decks can now be entirely eliminated in dairy buildings. This, of course, is a significant advance, and achieves considerable economies in the fabrication of a building.

The movement of goods and traffic within the building has been successfully catered for by mechanisation, and this has led to the floors being much more durable and capable of standing up to the work for longer periods, even though they have originally been built of less expensive materials than previously. Taking the work off the floors has been the major factor in this respect, and this course should be pursued with any new dairy building. The movement of traffic within the dairy has necessitated a technique of confining the hard-wearing and expensive floor surfaces to those lines on which the traffic must be used. Cold stores have also been influenced by this, and doors should be wide enough and high enough to allow mechanical devices to pass through with their different loads of commodities.

The advances that have been made by mechanical handling have shown that the design of a new dairy should not be too permanent, but should allow for possible expansion and/or modification in order to make the dairy capable of adopting a new mechanical process as it is evolved. The substantial buildings of the past, through being difficult and extremely expensive to modify, have in too many cases prohibited the use of some new mechanical-handling technique, and thus prevented some dairies from achieving real economies in work and costs.

Mechanical handling is being adopted at an ever-increasing rate today, and the above brief survey gives some indication of the high degree of mechanisation already achieved in certain branches. Throughout the world a vast amount of experimental work is being carried out to increase still further the mechanisation of some aspects of dairy work. Much of this, when developed, may necessitate fundamental changes in present day processing and handling, and the indications are that what is considered modern mechanisation today may very soon be rendered obsolete by entirely new techniques and methods.

This subject can be summarised very briefly for the liquid milk bottling industry by stating that the mechanisation which is being adopted in Western Europe is concerned chiefly with crating and uncrating machinery for bottles, and that in the United States for the mechanical stacking and unstacking of bottle crates. The transport of milk from the farm to the receiving dairy in road tankers is also being developed. This last naturally eliminates the use of cans and the can-washing and conveying-equipment in the dairy.

Refs.: Graham-Enock (1951), *JSDT*, **4**, 232; Inglis (1951), *MI*, **31**, No. 7 (7) 47; Procter (1948), *JSDT*, **1**, 136; Ritchie (1951), *JSDT*, **4**, 214; Sharkey (1949), *Austral. J. Dairy Tech.*, **4**, No. 3; White (1948), *JSDT*, **1**, 138.

MEDIA IN DAIRY BACTERIOLOGY. Peptone. Peptones have been unsatisfactory for various reasons and it is suggested that a specification should be agreed upon by dairy bacteriologists. The following is a tentative specification: (*a*) It shall be a granular solid (non-powdery) and give a pale-coloured, clear solution after heating and filtering. (*b*) A 1 per cent. solution of the peptone shall have a *p*H of 6·8 ± 0·2. (*c*) Its analysis shall lie within the following limits: Total nitrogen 12 to 15 per cent., non-protein nitrogen 6 to 10 per cent., moisture 6 to 8 per cent., ash 3 to 7 per cent. (*d*) A broth composed of 2 per cent. peptone, 2 per cent. dextrose and salts shall permit gas production and pigment formation by *L. rudensis* (this is a simple test for an adequate content of bacterial growth factors). (*e*) It shall be free from organisms resisting (in sugar media at *p*H 6·6) 3 steamings at 100° C. for ½ hr. (*f*) It shall be prepared by a defined and reproducible process. (*g*) At no time in the preparation shall the material be subjected to heat treatment greater than 50° C. at *p*H 8·0 or above. (*h*) It shall contain not more than 1 per cent. extraneous (insoluble) matter.

While it is desirable that as many types of micro-organisms as possible shall grow in the peptone medium, it is also important that those types commonly occurring in milk shall produce the largest possible colonies.

It should preferably be contained in screw-capped bottles.

" Natural " and " Artificial " Media. By " natural " media are understood extracts of plant and animal tissues or the materials themselves, *e.g.* meat and malt extracts, blood and milk. By " artificial " media are implied media incorporating specially prepared substances, such as peptone.

The ultimate goal of all bacteriologists is naturally the synthetic medium. For most of the organisms of economic interest in milk, synthetic media are unsuitable, and it is usual to employ artificial media. What is not generally realised, however, is that reproducibility, the all-important property of synthetic media, is poor in " artificial " media. Natural media are superior in cheapness and reproducibility, and are usually free from such undesirable features as heat-resistant spores and traces of toxic metals. Milk and malt extract are, for example, two of the most useful media for dairy bacteriologists. For special requirements, such as clearness and absence of sugar, digests of milk and of crude casein may be employed, enriched with malt extract or autolysed yeast when required.

Tests for Dysgenic Milk. By the term " dysgenic " applied to milk, is understood any condition which results in slow growth of bacteria, particularly the lactic acid bacteria. The condition is usually caused by disease in the udder of the cow from which the milk was obtained, but may be due to the growth products of certain micro-organisms. It is obvious that such milk must be avoided in making media.

In the morning fill out 10 ml. quantities of the milks to be tested (including, if possible, one known satisfactory milk) and momentarily autoclave. Inoculate each tube with 1 loopful (0·005 ml.) of a fresh milk culture of *Str. cremoris* at about 6 p.m. the same day and incubate at 25° to 30° C. overnight. Clotting should take place by 9 to 12 a.m. the following day (15 to 18 hr.). Any milk which has not clotted by 6 p.m. (24 hr.) should not be used for media.

Generally speaking, milk from cows free from mastitis is not dysgenic.

Yeast Autolysates. Plant extracts, such as those of malt or potato, may be as good as or even better than autolysed yeast as a source of growth factors for specific types of bacteria. When the absence of sugar is essential, however, they cannot be used and autolysed yeast becomes the most convenient source of these growth factors. It is especially valuable as an enrichment to peptone or casein digests in sugar fermentation tests. Although not quite free from sugars it may for practical purposes be so regarded, as the quantity finally present in the medium is very small. It is very difficult to prepare a satisfactory medium absolutely free from sugar, as proteins usually contain sugars as an integral part of the molecule.

Preparation of Yeast Autolysate. Crumble the yeast from a 7 lb. bag of Distillers' Company Ltd. bakers' yeast, place in a wide-mouthed lidded jar and stir in 1 per cent. of sodium chloride. Place in a 55° C. incubator for 6 days, stirring the mass at intervals. Filter into small flasks to take convenient quantities (*e.g.* 100 ml.) and autoclave for 10 min. at 120° C.

Reinforced Milk Media. ***Plant extracts.*** Although commercial "peptone" is the basis for media used in dairy bacteriology there is no logical reason for this. Peptone was devised by medical bacteriologists as a convenient basis for their media and has been accepted by dairy bacteriologists without any real investigation of the question. Milk, and digested milk and casein, should be regarded as the fundamental media, and where these are obviously deficient, as in the study of highly specialised types of micro-organisms, they should be suitably reinforced.

The yeast dextrose litmus milk described (p. 621) will grow all but a few highly specialised types for which the following media may be recommended. *Animal and human pathogens :* 1 per cent. blood (or 2 per cent. serum)—yeast dextrose litmus milk. *Vegetable mash, beer and wine strains of lactic acid bacteria :* 5 per cent. beer-wort, 1 per cent. autolysed yeast litmus milk. The beer-wort contains dextrose and other sugars. The additional constituents are incorporated at the time of making and sterilised with the medium. The litmus milk may be sterilised by 3 steamings or by momentary autoclaving. Autolysed yeast may cause a slight reduction of the litmus in the bottom of the tube after sterilising, but this is no disadvantage and may even be beneficial to some types.

Blood and serum. In dairy bacteriology blood or serum is seldom indispensable, as growth factors not present in milk may usually be added in yeast autolysate or plant extracts.

Although blood and serum may be added aseptically, this method is liable to give a contamination at any time and is a constant source of anxiety in pure culture work. It is recommended, therefore, that 1 per cent. blood and 2 per cent. serum milk media should be sterilised normally, Blood forms a slight brownish deposit after sterilising which is, however, only aesthetically objectionable.

The *preparation of blood* is carried out as follows : Shave a small area on the neck of a horse or cow, swab with 70 per cent. alcohol, and insert a sterile needle into the jugular vein, allowing the blood to flow through a sterile length of rubber tubing into a sterile bottle containing glass beads. Shake vigorously for 10 min. to defibrinate and place in the ice-chest for 24 hr. Decant the blood aseptically into sterile tubes, testing each tube for sterility by pouring a control plate at the time of use.

In preparing serum, ox or sheep blood is collected under conditions as aseptic as possible at the slaughter-house. It is allowed to stand for 15 min. to coagulate and placed in the ice-chest for 24 hr. The serum is then removed by a sterile pipette into a sterile flask and filled out into sterile tubes.

Solid Serum Medium is sterilised by inspissation (72° C. for 30 min. on 2 days and 90° C. on the third). Test for sterility by incubation for 1 day at 37° C.

Selective and Differential Media. Plating on selective[1] and differential[2] media is frequently carried out in dairy bacteriological laboratories both for economic and public health reasons. It is not generally realised that selective media are nearly always not only inhibitory to other types of organisms but also partially inhibitory to the organisms under investigation. Counts obtained on selective media are therefore usually lower (for a given organism) than those obtained on ordinary media. Differential media may or may not be inhibitory for other organisms. Thus, for milk, blood agar gives as high a count as milk agar, but tributyrin agar inhibits growth of many organisms. Differential media described in the literature frequently give disappointing results in other laboratories. When such differential counts are in common use for the assessment of the quality of a product, it is obviously desirable that differentiation should be reasonably clear cut, otherwise confidence in the result is lacking. The best differential media from this point of view are (i) blood agar; (ii) gelatine; (iii) B.C.P.-chalk lactose agar, and (iv) tributyrin agar. Other differential media, of which those for detecting caseolysis are probably the most important to the dairy bacteriologist, have not given entirely satisfactory results, *i.e.* the proportion of " doubtful " zones is appreciable.

***p*H Adjustment of Media : The Titration of Milk.** Whereas in the titration of simple acid solutions the amount of indicator added is of no great significance, a very different result is obtained when milk is used. For adjusting milk to *p*H 2 for peptic digests, 2 ml. of 0·1 per cent. thymol blue (or an equivalent amount of indicator) should be added to 10 ml. of milk. For pancreatic digests add 1 ml. of phenol-phthalein.

The " Buffer Method " of Adjusting Media to Specified *p*H Values. The adjustment of media, etc., to specified *p*H values is one of the most important techniques used by biological workers. Discussion of the problem with various workers has shown that a number of haphazard methods are in use in different laboratories.

LIST OF INDICATORS

Indicator	*Colour range*
Thymol blue	1·2 (bright pink); 2·0 (salmon pink); 2·8 (yellow).
Bromphenol blue	3·1 (greenish yellow); 3·9 (grey); 4·7 (bluish purple).
Bromcresol green	3·8 (green-yellow); 4·6 (bluish green); 5·4 (deep blue).
Chlorphenol red	5·1 (orange-ochre); 5·9 (crushed strawberry); 6·7 (magenta).
Bromcresol purple	5·4 (greenish yellow); 6·3 (purplish grey); 7·0 (purple).
Bromthymol blue	6·1 (green-yellow); 6·9 (blue-green); 7·7 (deep blue).
Phenol red	7·0 (orange-ochre); 7·8 (orange-pink); 8·6 (red-magenta).
Cresol red	7·4 (ochre); 8·2 (dull grey purple); 9·0 (reddish purple).
Thymol blue	8·0 (green-yellow); 8·8 (blue-green); 9·6 (deep blue).
Thymol phthalein	9·3 (colourless); 10·0 (pale blue); 10·5 (blue fades).

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[1] A " selective " medium is one permitting the growth of only certain types of organisms.

[2] A " differential " medium is one differentiating organisms by visual or chemical means.

The method proposed depends on two principles: (1) Any solution may be adjusted *approximately* by colorimetric methods. (2) A buffer mixture at any *p*H required may be prepared by weighing out the appropriate amounts of salt and acid (or measuring appropriate volumes of solutions).

The solution or medium is first adjusted to the approximate *p*H, using a suitable indicator disc in a comparator, by adding HCl or NaOH. It is convenient to have N and 5N solutions at hand.

It is important to heat the medium or solution before adjustment to the required *p*H. The medium should then be left 15 min. in order to attain equilibrium, because most media contain colloidal systems which attain ionic equilibrium slowly. When the medium has been adjusted approximately by using a comparator the appropriate buffer mixture is added, preferably in the solid form. Care must be exercised in the choice of buffers, since some may be toxic or interfere with the reaction to be studied. The following may be recommended:

Buffer	*p*H *range*
Hydrochloric acid—potassium chloride	1·1 to 3·1
Hydrochloric acid—glycine	1·1 to 3·4
Acetic acid—sodium acetate	3·7 to 5·6
Citric acid—potassium citrate (Table Md I)	2·0 to 6·0
Citric acid—sec. sodium phosphate (Na_2HPO_4) (McIlvaine) . .	2·0 to 8·0
Prim. potassium phosphate (KH_2PO_4)—sec. sodium phosphate .	5·8 to 7·8
Glycine—sodium hydroxide	8·5 to 10·5 and 12·3 to 13·0
Sec. sodium phosphate—tertiary potassium phosphate (K_3PO_4) . .	10·5 to 12·0

(1) In highly acid agar media (*p*H below 4·5) the addition of *previously sterilised* buffer mixture + necessary acid should be made when the medium has cooled down to 90° C. after autoclaving at neutral reaction. Filling out is done aseptically at 80° to 90° C. Avoid keeping such media at 100° C. for more than a few minutes, as otherwise the agar may be hydrolysed.

TABLE Md I

CITRIC ACID—POTASSIUM CITRATE BUFFER

Parts citric acid monohydrate	*Parts potassium citrate monohydrate*	*p*H
9·5	0·5	2·23
9·0	1·0	2·44
8·5	1·5	2·67
8·0	2·0	2·90
7·5	2·5	3·06
7·0	3·0	3·26
6·4	3·6	3·50
6·0	4·0	3·64
5·5	4·5	3·87
5·0	5·0	4·10
4·5	5·5	4·31
4·0	6·0	4·53
3·5	6·5	4·74
3·0	7·0	4·96
2·5	7·5	5·20
2·0	8·0	5·43
1·5	8·5	5·71
1·0	9·0	5·98

(10 to 20 per cent. of 10 per cent. buffer solution may be incorporated in the medium.)

(2) Phosphates accelerate the conversion of sugars into lactic and other acids by heat. They also depress proteolysis and decrease the bacterial count of a mixed flora such as that found in milk. On the other hand, phosphates increase

the growth of the preferentially saccharolytic types such as the coli-aerogenes bacteria, yeasts, and the lactic acid bacteria.

(3) The citric acid-citrate buffer is one of the most suitable for media preparation as citrates do not appear to exercise any harmful effect and are known to stimulate some metabolic reactions. For *p*H values between 6 and 8 phosphate buffer and for values between 8 and 10 glycine—NaOH buffer are recommended. The precipitation of calcium at *p*H 8 and above does not appear to be complete enough to interfere with bacterial growth.

(4) 1 or 2 per cent. buffer is suitable for ordinary work. 2 per cent. citrate has, in fact, been found to enhance the value of some media.

The *p*H Adjustment of High Sugar—Low Buffer Value Media. It has been found that "neutral" (*p*H 6·8) beer-wort agar taken from the store had a *p*H of about 5·5. The error was ultimately tracked down to the fact that autoclaving was employed and that the media had not been tested for *p*H after sterilising.

Ordinary peptone media only change about 0·2 *p*H units on autoclaving. The explanation lies in the $\frac{\text{sugar}}{\text{buffering substances}}$ ratio of the different media. Thus dextrose agar may have 1 per cent. dextrose and 1 per cent. peptone plus 1 per cent. lemco. Beer-wort has about 1 per cent. "peptone" and about 12·5 per cent. reducing sugars (as dextrose). The ratio is thus approximately 0·5 for dextrose agar and 12·5 for beer-wort. As the amount of acid formed on heating will be proportional to the concentration of sugar, and the change in *p*H inversely to the amount of buffering substances present, the reason for the drastic effect of autoclaving on the beer-wort is evident.

Three steamings have slightly more effect than autoclaving momentarily at 120° C. It should be noted that phosphate and hydroxyl ions catalyse the reaction sugar → acid (chiefly lactic acid). The incorporation of a phosphate buffer, therefore, may not necessarily be an advantage.

All media having a high sugar-"peptone" ratio should be tested for *p*H after sterilisation.

Indicators in Media. For many purposes it is desirable to incorporate indicators into media, especially in sugar fermentation tests and for those differential media whose value depends on acid production, such as the bile salt lactose media in common use for detecting coliform organisms. It is somewhat surprising, therefore, to see recommended indicators which are not the best available and give misleading results. For example, neutral red in MacConkey broth is reduced in acid solution to a yellow form indistinguishable from the neutral or alkaline form. This has resulted in much confusion amongst routine workers not aware of this behaviour.

Of all the indicators available, the sulphonphthaleins are easily the best for bacteriological purposes. They are strongly coloured, chemically definable, and are not reduced to other coloured forms by bacteria. They are thus reliable indicators and should be used whenever possible. The following are the best from the bacteriological point of view: Phenol red (for *p*H ranges *see* p. 674); Bromthymol blue; Bromcresol purple; Bromcresol green; Bromphenol blue (less satisfactory). They may be incorporated in media at a concentration of 0·002 to 0·004 per cent. A convenient method is to dissolve 1 g. in a little distilled water containing 20 ml. of $\frac{N}{10}$ NaOH (the slight difference from the theoretically required amount is of no consequence) and make up to 2½ litres with distilled water. Incorporate 5 per cent. of this solution in the medium ($\equiv$ 0·002 per cent. of indicator).

In determining sugar fermentations it may be desirable to estimate the change of *p*H over a rather wider range of *p*H. A number of combinations of these indicators have been tried out in media and, considering all aspects, the following was found to be the best: Bromcresol green, 0·001 to 0·002 per cent. Bromcresol purple, 0·001 to 0·002 per cent. This mixed indicator has the following range:

Colour	*p*H
Deep blue	7·0
Indigo	6·0
Green	5·0
Greenish-yellow	4·0
Bright yellow	3·5

Using this mixed indicator in sugar broths it is possible to estimate the final *p*H attained with an accuracy of about 0·2 *p*H units, except where adsorption takes place.

Sterilisation of Media. The following suggestions are made:

(1) Autoclave all non-sugar media at 120° C. for 15 min.

(2) If steaming is used for sugar media test *all* tubes by incubation at 37° C. for 1 day, as heat-resistant organisms tend to have a high-temperature optimum for growth.

(3) Aseptically taken nutrients (*e.g.* blood) should be rigorously tested under the conditions of use. Thus it has been found that a sample of blood gave no growth on nutrient agar but did so in litmus milk, both media having passed sterility tests. When autoclaving at 120° for 15 min. is inadvisable, the method of *momentary autoclaving* may be employed for tubed media. This involves heating up to 120° and then turning off the heat. The temperature is above 100° for 20 to 30 min., the media attaining a temperature of 116° to 118° C.

MEDIA FOR ROUTINE CONTROL PURPOSES

(i) ***Blood agar* (*for haemolytic organisms*).** Prepare nutrient agar (1 per cent. peptone, 1 per cent. lemco, 0·5 per cent. sodium chloride, 2 per cent. agar, *p*H 7·4), and add 5 per cent. of defibrinated blood to the melted medium at 45° to 48° C. After pouring, incubate plates at 37° C. for 2 days, examining also after 1 day. (For cases of doubtful haemolysis *see* Davis and Rogers (1939), *JH*, **39**, 446.)

(ii) ***Gelatine media* (*for proteolytic organisms*).** Usually the agar is replaced by 20 per cent. gelatine. The chief disadvantage of gelatine media is liquefaction of the entire plate. This may be avoided by incorporating 0·5 per cent. agar in the medium and examining at frequent intervals.

Mercuric chloride is the best protein precipitant to use for flooding gelatine plates, but its use is inadvisable in bacteriological laboratories. Freshly prepared 1 per cent. tannic acid solution can be recommended. As a high degree of correlation (about 90 per cent.) exists between gelatine liquefaction and tributyrin hydrolysis, it is usually unnecessary to estimate numbers of gelatine liquefying *and* lipolytic organisms.

(iii) ***B.C.P.-chalk lactose* (*or dextrose*) *agar* (*for acid producers*).**

	%
Lactose (or dextrose)	1·0
Peptone	0·3
Lemco	0·3
Yeastrel	0·3
Separated milk	1·0
Agar	1·5
Chalk (fine precipitated)	1 to 2
Bromcresol purple solution (0·04 per cent.)	5·0
Adjust to *p*H 6·8	

When filling out into tubes, the flask must be kept continuously shaken. The size of the clear zones is a reliable indication of the acid-producing power of the colony.

(iv) ***Tributyrin agar* (*for lipolytic organisms*).** Prepare a nutrient agar (0·3 per cent. peptone, 0·3 per cent. lemco, 0·3 per cent. yeastrel, and 1·5 per cent. agar), and after heating and filtering, add 1 or 0·5 per cent. tributyrin and emulsify the medium at a temperature of 90° C. with a hand (pump type) emulsifier. Tube in 10 ml. quantities. The final *p*H should be 7·0 to 7·5. The quality of peptone and the exact *p*H are not important. Colonies may be differentiated into strong (zones 3 mm. or more wide—edge of colony to edge of zones) and weak (zones $<$ 3 mm. wide) lipase producers.

Victoria blue (or night blue) butterfat (*see* p. 151). Jones and Richards (1952), *SAB*, **15**, 82. Dissolve 1 g. dye in 1500 ml. water. Night blue requires a few drops of conc. HCl.

Freshly made butter is melted at 55° C., filtered and the curd-free oil autoclaved.

The basal medium contains 1 per cent. peptone, 0·3 per cent. yeastrel, 0·5 per cent. sodium chloride, and 2 per cent. agar, and is adjusted to *p*H 7·8. Incorporate 100 ml. of 1 in 1500 dye solution in 1 litre of medium. After filling out into tubes sterilise by autoclaving.

For use add 5 per cent. butterfat to each tube and sterilise. After cooling to 48° C., fit a sterile rubber stopper and shake about 25 times in 10 sec. with an excursion of 1 ft. Stand for 5 min. at 48° C. to allow the froth to subside and then pour in the usual way. *See* Lipolytic organisms.

(v) ***Milk agar.*** Ordinary milk agar may be used for the detection of caseolytic organisms. A higher concentration of milk may be used (2 to 3 per cent.) if desired. The small amount of sugar in the medium (0·05 to 0·15 per cent.) will tend to reduce caseolysis, but as sugar (or the resultant acid) is normally present in dairy products, this is not a serious disadvantage. The plate may be flooded with freshly prepared 1 per cent. tannic acid solution to confirm whether colonies produce true caseolysis.

(vi) ***Casein agar*** (Frazier and Rupp (1928) ***JB***, **16**, 57). This has been found to be the best medium for estimating the number of caseolytic organisms in dairy products, but is somewhat laborious to prepare.

(vii) ***Yeasts and moulds, media for.*** Almost any medium is satisfactory for growing yeasts and moulds provided it contains sugar and a plant extract. Unhopped beer-wort and malt extract are convenient for this purpose.

It is customary to adjust the *p*H of such media to 3·5 to inhibit the growth of bacteria. This device is adequate but it should be realised that this high acidity results in some lowering of the total count, but this is not important from the point of view of routine counts of yeasts and moulds in such products as butter, condensed milk and cheese.

Preparation of beer-wort. Wort as received from the brewery should be heated to 100° C. for 1 hr., filtered through pulp, cooled to 20° C. and an equal volume of tap water added. The wort should be sterilised in 1 litre quantities by 3 steamings at 100° C. for 1 hr.

*Adjustment of p*H. This is most conveniently made by adding the approximate amount of citric acid monohydrate required to bring the *p*H down to *about* 3·5, and then stabilising at *p*H 3·5 by addition of buffer (p. 130). Diluted beer-wort requires 2 g. of the acid per l. to bring the *p*H to 3·5 ; 12·8 g. of the acid and 7·2 g. of potassium citrate monohydrate should then be added per l. to buffer the medium at *p*H 3·5.

*Preparation of beer-wort agar p*H 3·5. Add 2 per cent. agar to beer-wort prepared as described above. Autoclave to dissolve and add the acid and citrate previously sterilised in a little water to the beer-wort at 90° C. Fill out into test-tubes *and do not resterilise* or the agar will be hydrolysed.

In use melt the agar as quickly as possible and use immediately. Do not keep the agar at 100° C. or hydrolysis will result.

(viii) ***Milk agar (unfiltered).*** Dissolve 5 g. peptone and 3 g. lemco (or yeastrel) in 1 l. of tap water, adjust to *p*H 6·8, add 15 g. washed agar, autoclave for 20 min.

at 120° C., filter, add 10 ml. raw skim milk, tube and autoclave for 10 min. at 120° C. The medium is more turbid than yeastrel agar and consequently lessens the glare in counting. A number of advisory and commercial dairy bacteriologists who have been consulted on this point expressed their preference for unfiltered milk agar.

Milk and Casein Digest Media. The following media are suggested as substitutes for ordinary peptone broth and agar media for the cultivation of the common milk bacteria, particularly such highly specialised types as *Str. thermophilus*, *Str. cremoris*, and *L. bulgaricus*.

The milk digests form excellent substitutes for sugar peptone media, and the casein digests for peptone. The addition of autolysed yeast is usually advantageous. These media can be prepared in 2 days and involve no technically difficult or complicated operations.

The one essential for preparing a good digest is an active enzyme preparation. The British Pharmacopœia test is a satisfactory one to apply to pepsin and pancreatin. Experience has shown that these enzymes lose their activity at uncertain rates and that the best safeguard is to use freshly prepared materials. Small quantities should be ordered as required, therefore, and the B.P. standard insisted upon.

(ix) ***Milk double digest broth (a).*** Procure sufficient fresh separated milk for the amount of medium required and titrate 10 ml. quantities as follows:

(1) Add 1 ml. of 0·5 per cent. phenolphthalein in 50 per cent. alcohol and titrate with N/10 (or N/9) NaOH. A control flask containing 10 ml. milk and 2 ml. of the NaOH solution should be used.

(2) Add 2 ml. of 0·1 per cent. thymol blue (or an equivalent amount of indicator) and titrate with N/10 HCl until the colour changes from yellow-orange to salmon pink. About 15 ml. will be required. A control flask containing milk and indicator should be used. Calculate the amount of N NaOH required to adjust half the milk to the end-point of phenolphthalein (*p*H 8·4) (about 17 ml. per litre) and of 5 N HCl (*b*) to adjust the other half to the end-point of thymol blue (*p*H 2) (about 30 ml. per l.). The optimum *p*H for a peptic digest is about 2 and for a pancreatic (tryptic) digest about 8·4.

Add to half this milk 0·5 per cent. pancreatin and to the other 0·5 per cent. pepsin. Shake and stand 15 min. Then add the calculated amount of N NaOH to the pancreatin milk together with 1 per cent. chloroform (*c*), and of 5N HCl to the pepsin milk. Shake well and place the pepsin milk in the 45° C. and the pancreatin milk in the 37° C. incubator for 48 hr. Shake well at intervals. Mix the two filtrates (*a*) (add 1 per cent. autolysed yeast (*d*) if desired), adjust the *p*H to 6·8, steam, filter overnight, and fill out into tubes or flasks. If desired these may contain chalk, previously moistened and sterilised by heating to 165° C. for 3 hr. (dry heat). Sterilise by autoclaving tubes momentarily at 120° C. and flasks by three steamings at 100° C.

(x) ***Milk double digest agar*** is as for the broth, but add 1·5 per cent. agar after mixing the solutions and omit the chalk.

NOTES

(*a*) Peptic and tryptic digests are each suitable for some types of bacteria. By combining the two digests a more general medium is obtained. If only streptococci are to be grown, the peptic digest should be used; if lactobacilli, the pancreatic digest may be employed.

(*b*) Concentrated HCl is about 10 N. Dilute 100 ml. concentrated HCl to 200 ml., titrate 5 ml. with N NaOH (about 27 ml. required), and add water to make 5 N.

(*c*) Chloroform is only required in the pancreatic digest; the acidity of the peptic digest inhibits bacterial growth.

(*d*) Good growth of the typical milk bacteria is obtained without yeast. The addition of the yeast results in somewhat better growth.

(xi) ***Casein double digest broth*** **(*a*) (for 4 l.).** Mix together 120 g. casein (*b*), 2 l. tap water, and 120 ml. N NaOH. Shake well and stand for about 1 hr. at room temperature (*c*). Divide the solution into halves. Prepare a solution of 10 g. pepsin in 168 ml. N HCl and add this to one-half of the sodium caseinate solution and mix thoroughly. Prepare another solution of 10 g. pancreatin in water containing 21 ml. N HCl, add this to the other half and shake thoroughly. Adjust the peptic digest to *p*H 2 and the pancreatic to *p*H 8·4 if necessary, using a "spotting" plate. Make up each solution to 2 l. and place the pancreatin with 1 per cent. chloroform in the 37° and the peptic digest in the 45° C. incubator for 48 hr.

Mix the two solutions, add 130 ml. N NaOH and shake thoroughly. Add 5 per cent. yeast autolysate if desired. Adjust the *p*H to 6·8 (bromthymol blue), steam for 1 hr. at 100° C. and filter overnight. Readjust the *p*H if necessary and fill out into sterilised tubes or flasks. If a sugar is to be sterilised with the medium, autoclave momentarily at 120° C. Flasks should be steamed. Otherwise autoclave at 120° C., tubes for 10 min., and flasks (250 ml.) for 20 min.

NOTES

(*a*) Casein digest is suitable as a "peptone" in dairy bacteriological work and as a nitrogen source for sugar fermentation tests.

(*b*) The casein should be as free from fat as possible but otherwise unpurified. New Zealand "Anchor Brand" may be recommended. Purification of the protein impoverishes the medium.

(*c*) Peptic casein digests prepared without this preliminary step proceed slowly on account of the small amount of contact between the insoluble casein (frequently fat-film covered) and the enzyme.

(xii) ***Milk serum.*** Milk serum is a convenient clear medium which contains all the soluble substances of milk. As it is low in nitrogen it should be supplemented with peptone and, although it is fairly rich in growth factors, yeast autolysate can be added with advantage.

It is prepared as follows: Warm 1 l. of fresh whole or separated milk to 40° C., add slowly with stirring 70 ml. of N (7 per cent.) citric acid. Stand for about 1 hr. and then start to filter, leaving it overnight. Remove the serum (about 600 ml.) into flasks and steam once for 1 hr. (as the *p*H is about 4·7 this is sufficient). When required for use, adjust to *p*H 6·8 (bromthymol blue) with N NaOH (about 40 ml. required).

A convenient solid medium for general purposes is the following: 1000 ml. milk serum (*p*H 6·8); 10 g. peptone; 10 ml. yeast autolysate; 15 (or 20) g. agar.

(xiii) ***Litmus milks. Preparation of litmus solution.*** Heat 120 g. litmus granules in 2000 ml. distilled water at 80° C. for ½ hr. Filter and add glacial acetic acid until a bright red colour is obtained (about 15 ml.). Evaporate to a thick paste, transfer to a filter and wash with absolute alcohol. Dissolve the residue in 250 ml. distilled water at 70° C., filter and sterilise by 3 steamings for ½ hr. on successive days.

Litmus milk. Separated milk + 1 per cent. litmus solution.

Dextrose litmus milk (for non-lactose fermenting organisms). Litmus milk + 1 per cent. dextrose.

Yeast litmus milk (for plant types). Litmus milk + 1 to 5 per cent. autolysed yeast extract (p. 673).

Yeast dextrose litmus milk (a very rich medium for fastidious organisms). Litmus milk + 1 per cent. dextrose + 1 to 5 per cent. autolysed yeast extract.

Filtration of Media. Bacteriologists usually endeavour to obtain clear media. Filtration, however, tends to make media less effective from the growth-promoting point of view. This arises not so much from the removal of nutrients as from the value of solid particles in the medium as " growth centres ". This is especially noticeable with the more aerophobic species and the anaerobes. It is usually preferable not to filter media such as meat and vegetable extracts. If cells free from media debris are required, they may be so obtained by differential centrifuging of the well-shaken culture, *e.g.* spinning momentarily at 2000 to 3000 r.p.m. to throw down chalk, tissue, etc., and then centrifuging the clarified medium for 20 to 30 min. at a higher speed to throw down bacterial cells.

As an example of this general principle may be mentioned the superiority of *unfiltered milk* agar, which has the following advantages over the filtered medium : (1) It sometimes gives higher counts and larger colonies. (2) It provides a better background in the counting chamber. (3) It is easier to prepare.

***Str. Agalactiae*, Diagnostic Medium for.** When non-blood media are used, it is essential to pick off suspected colonies for confirmation by biochemical or serological tests. Even when blood media are used it is advisable to carry out this procedure in all but the very obvious cases, *i.e.* with plates containing numbers of small light-coloured colonies surrounded by zones of " weak β " haemolysis.

The most characteristic properties of *Str. agalactiae* are (i) hydrolysis of hippurate, (ii) acid and clot without reduction in yeast litmus milk, (iii) non-fermentation of aesculin, and (iv) orange deposit in starch broth cultures.

Of these, the first and fourth are probably the most peculiar to *Str. agalactiae*. While it would be possible to combine these tests in one medium, it may be observed that testing for hippurate hydrolysis is a matter requiring some skill and also that the formation of the orange pigment with starch is only evident in abou 80 per cent. of strains examined. The remaining two properties are, as far as we have observed, constant. The following medium has been devised to permit the determination of these reactions in a simple and convenient manner :

Separated milk	1000 ml.
1 per cent. litmus solution	10 ml.
Autolysed yeast	10 ml.
Aesculin	5 g.
5·8 per cent. ferric chloride solution (commercial 58 per cent. diluted 10 times)	1 ml.

Adjust to *p*H 7·0, fill out into tubes and sterilise by intermittent steaming or momentary autoclaving.

Procedure. Any medium permitting the growth of *Str. agalactiae* may be used for the plating provided this is carried out within 3 hr. of milking. Well-isolated colonies presumed to be *Str. agalactiae* are picked off into tubes of the medium, incubated at 37° C. for 48 hr. and then examined. At least three whole colonies should be picked off.

Diagnosis. Acidity and clotting without reduction of the litmus and without darkening of the medium may be taken as presumptive evidence of *Str. agalactiae* (Table Md II).

This characteristic reaction is produced by *Str. agalactiae* and also by some non-aesculin fermenting strains of *Str. pyogenes*. The latter are rare in properly taken udder samples, and even if diagnosed as *Str. agalactiae* in eradication schemes no harm is done, as such streptococci should rightly be regarded as undesirable. The use of blood media for the plating usually permits the differentiation of *Str. pyogenes* from *Str. agalactiae*. *Str. thermophilus* produces a similar reaction in this medium but is not known to occur in udder samples.

In Table Md II are given the appearances of the medium after growth of organisms likely to occur in udder samples.

Ferric chloride has two functions in the medium : (1) To give a black colour with the decomposition products of aesculin (aesculetin), and (2) to inhibit the slight tendency of some strains of *Str. agalactiae* to reduce litmus in yeast litmus milk. It has been found, in fact, that all organisms which normally bring about a slight reduction of litmus in milk no longer do so when ferric chloride is incorporated in the medium. It is possible to control the extent of reduction by varying the concentration of ferric chloride. The addition of the yeast autolysate ensures rapid and certain growth of all colonies of *Str. agalactiae*.

TABLE Md II

Organism	*Acidity*	*Clot*	*Reduction*	*Darkening*	*Catalase*
Str. agalactiae . . .	+	+	0	0	0
Str. bovis	+	±	0	+	0
Str. lactis	+	+	+ +	+	0
Str. faecalis . . .	+	±	+ +	+	0
Str. pyogenes . . .	+	+	0	±	0
Str. salivarius . . . (" viridans ")	+	+	+ +	+	0
Str. dysgalactiae . . . (Minett Group II)	+	+	+ +	+	0
Str. uberis (Minett Group III)	+	+	+	0	0
Udder cocci . . . (lactose fermenting)	+	+	+	±	+
Udder cocci . . . (non-lactose fermenting)	0	0	0	0	+

Reduction : + – partial reduction of litmus ; + + complete reduction of litmus.
± variable.

Udder cocci are readily differentiated by the catalase test. This may be carried out by adding 1 ml. of 10 vol. hydrogen peroxide to the culture or by adding 1 ml. of the culture to *c*. 3 vol. hydrogen peroxide preferably in phosphate buffer at *p*H 6·8. A steady evolution of small bubbles indicates a catalase-positive organism, probably a " micrococcus ". All streptococci are catalase negative.

MATERIALS FOR MEDIA. Table Md III gives a list of constituents and Table Md IV a list of media which should be available in a well-equipped dairy bacteriological laboratory.

TABLE Md III—MATERIALS FOR MEDIA

Agar
Peptone
Meat extract (Lemco)
Gelatine
Yeastrel
Beer-wort
  (unhopped)
Malt, dried
  or extract
Potato
Blood
Bullock's heart
Liver
Meat, lean
Casein

Dextrose, lactose, and other sugars
Bile salt
Tributyrin
Salt (sodium chloride)
Chalk (calcium carbonate)
Citric acid
Potassium citrate
Potassium nitrate
Potassium tellurite
Hydrochloric acid
Sodium hydroxide
Methylene blue, eosin and crystal (gentian)
  violet
Pepsin and pancreatin

TABLE Md IV—MEDIA

Routine control work

Milk or yeastrel agar
MacConkey (coli) broth
Litmus (or bromcresol purple) milk

Additional media for advisory work

Bromcresol purple chalk agar.
Gelatine

Additional media for advisory work—(*contd.*)

Tributyrin agar
Blood agar (nutrient agar + 5 per cent. defibrinated blood)
Nutrient agar
Citric acid beer-wort agar *p*H 3·5
Beer-wort agar *p*H 6·8
Yeast dextrose litmus milk, with and without chalk.
Casein agar
Crystal violet agar
MacConkey agar

Additional media for research

Sugar broths (arabinose, dextrose (glucose), lactose, sucrose, maltose, raffinose, salicin, aesculin and mannitol are most useful)

(The purest sugars should be used for these tests and these are best sterilised separately)

Peptone water
Meat extract broth
Dextrose broth
Potato (neutralised)
Yeast litmus milk
Dextrose litmus milk
Standard agar
Robertson's cooked meat medium
Casein digest (peptic and pancreatic) broth and agar
Nitrate peptone water
Liver agar
Bullock's heart medium
Tellurite broth and agar
Bromcresol purple peptone milk
Koser's citrate agar
Methylene blue eosin agar
Czapek's nitrate sucrose agar

See Abnormal milk ; Coliforms ; Laboratories ; Lactic acid bacteria ; Mastitis ; Plate count.

Refs.: Levine and Schoenlein, *A Compilation of Culture Media;* Wilson and Miles ; Chalmers ; Cunningham ; Eyre ; Wilson *et al.*

MEMBRANE, FAT GLOBULE. Much confusion has existed about the identity of the substances forming the membrane which prevents the globules from coalescing. Various workers have claimed it to consist of lactomucin (p. 690), casein and globulin, lipoids, calcium soaps, and new proteins. It seems probable that it consists mainly of phospholipoids and a protein or proteins not completely identical with casein, albumin, or globulin. *See* Cream layer.

Refs.: Rogers ; Palmer and Wiese (1932), *JDS*, **15**, 371 ; (1933), **16**, 41 ; (1934), **17**, 29.

MENADIONE. *See* Keeping quality.

MERCURIC CHLORIDE. A powerful preservative which is sometimes used for milk samples. Its use is to be deprecated because of its poisonous nature and possible effect on bacteriological glassware.

METABOLISM. A general term for all chemical activities of living organisms. It includes respiration, fermentation, proteolysis, lipolysis, and all chemical changes brought about by enzymes.

In dairying its significance lies in the factors affecting milk secretion (p. 728), especially the quantity and quality of the milk, and in faults in milk and dairy products which are due to the chemical activities of micro-organisms. Certain aspects of bacterial metabolism are made use of to assist in the identification and classification of bacteria (p. 62). *See* Cheese, p. 168 ; Coliforms ; Digestion ; Enzymes ; Flavours ; Lactic acid bacteria ; Milk secretion ; Stability.

Refs.: Stephenson ; Gale ; Ajl (1951), *BR*, **15**, 211 (respiration micro-organisms); Kluyver (1952), *CI*, **136** ; Stanier (1950), *BR*, **14**, 179 (bacterial oxidations)

METALS. For Dairy Equipment. It is now generally agreed that stainless steel is by far the best metal for all dairy plant. It is also used for tankers and storage tanks. Where this is unsuitable or uneconomic, tinned mild steel may be used, as in milk churns. The use of tinned copper as in old types of coolers, tanks, and dairy equipment, cannot be recommended as bare patches of copper inevitably appear sooner or later and may be the cause of oiliness. *See* Flavours.

Aluminium has been tried for tankers and churns and, when the right alloy has been found, it is likely that there will be a great extension of the use of this metal.

Bronzes and brass are still used to some extent, especially for those parts in which fabrication in stainless steel is expensive, but the less used the better. *See* Aluminium ; Copper ; Metals, alloys and corrosion ; Monel metal ; Nickel ; Stainless steel ; Tin.

Refs.: Farrall; Seligman (1952), *JSDT*, **5**, 170; Waite (1947), *JSDT*, **1**, 8; Speight (1947), *JSDT*, **1**, 13 (stainless steel); Bradbury (1947), *JSDT*, **1**, 23 (nickel); Lewis (1947), *JSDT*, **1**, 27 (tin); West (1947), *JSDT*, **1**, 31 (aluminium); Min. Works (1944), " Non-ferrous Metals ", H.M.S.O.

METALS, ALLOYS AND CORROSION IN THE DAIRY INDUSTRY. Of the great number of metals and alloys known to modern technology, comparatively few are in common use in the dairy industry. Probably the whole of dairying could be carried on efficiently in equipment consisting of iron and stainless steel, copper, nickel and aluminium and their alloys with tin and zinc as protective coatings to some of these. The past few years have seen an increasing tendency to employ stainless steel only where milk and its products come into contact with metals, so that at the present time selection of a suitable metal for a process in the dairy industry often means choosing the most suitable stainless steel Despite their costliness, these alloys are now seriously considered for such elementary items as churns and buckets, and for other equipment where older metals have, in fact, given good service.

Steel and Cast Iron. Steel and cast iron are essentially alloys of iron and iron carbide. As a matter of convenience, metallurgists distinguish between steel and cast iron by terming alloys containing less than 1·7 per cent. carbon as " steels ", while those having more are called " irons ". The cast irons containing their carbon as carbide, Fe_3C, are known as " white " cast irons, while the " grey " cast irons contain in addition much free carbon in the form of graphite. In white cast irons, the presence of the hard carbide, Cementite, makes the metal hard and non-ductile, while the graphite flakes in the grey irons results in easy machinability, and give rise to the characteristic gray fracture. In both series, alloy irons are obtained by addition of elements such as nickel, silicon, copper, chromium, and molybdenum; such alloys are very numerous, and have been developed in many cases to satisfy specific conditions of service. The ordinary grey cast irons are those most likely to be met in dairy plant, and this material is more resistant to many types of corrosion than the carbon steels. In the case of ordinary rusting, for instance, continued penetration by rust is significantly slower than for mild steel because the graphite flakes form a protective layer. Resistance to alkaline solutions is good, but acid resistance, especially where hot dilute mineral acids are concerned, is low.

Steel is produced from molten pig iron by removing carbon and other impurities by blowing a blast of air through it. This is known as the Bessemer process. Open Hearth furnaces in which pig iron is heated with iron ore by producer and other gases are also much employed. The carbon content of steels varies from less than 0·1 per cent. to over 1 per cent. for a hard tool steel, and the plain carbon steels are, in fact, usually divided into classes according to their carbon content:

(*a*) Carbon up to 0·15 per cent., which includes steels used for nails, rivets, tubes, hot rolled strip, etc.

(*b*) Mild steel with carbon between 0·15 and 0·25 per cent. These steels are used very widely, especially in the form of section steel for building. They have tensile strengths of about 30 tons per square inch.

(*c*) Carbon from 0·25 per cent. to 0·5 per cent.; such steels are used for parts where higher strength than that of mild steel is required. Examples are for forgings, boiler drums and ordinary implements like shovels and spades.

(*d*) The higher carbon steels with carbon over 0·5 per cent. are used for resisting wear. The higher the carbon, the greater the hardness which is obtained at the expense of ductility.

Table Me I shows how the Ultimate Tensile Strength, ductility and impact resistance of the plain carbon steels varies with carbon content.

TABLE Me I

Carbon %	*U.T.S.* (*tons/sq. in.*)	*Elongation* %	*Izod value* (*ft. lb./sq. in.*)
0·14 (normalised)	27	44	90
0·25 (normalised)	31	34	60
0·35 (annealed) .	43	27	54
0·65 (tempered) .	62	17	5
1·56 (as rolled) .	48	2	1

Of the above types, those containing 0·2 to 0·25 per cent. carbon are those most usually met in dairy equipment and buildings. Their behaviour, either mechanical or from a corrosion point of view, is typified by that of mild steel, which is too well known to need further description. The rusting process is explained later (Figs. Me 13 and 14), and water line attack which often appears on steel (Fig. Me I) is described under Aluminium (p. 687).

In addition to the many modifications of properties effected by heat treatments, incorporation of other elements such as manganese, silicon, chromium, cobalt, molybdenum, and tungsten cause further profound changes. Such alloy steels exist in great profusion and for an account of their properties, standard text books should be consulted (Bain, 1941; Rolfe, 1942).

TABLE Me II

Metal	*BS.* 1470	*Al* % (*min.*)	*Cu* % (*max.*)	*Mg.* %	*Fe* % (*max.*)	*Si* %	*Mn* %
Aluminium	SIA	99·8	0·02	—	0·15	0·15	—
	SIB	99·5	0·05	—	0·40	0·30	0·05
	SIC	99	0·10	—	0·7	0·50	0·10
Al/Mn .	NS3	Rem.	0·15	—	0·75	0·60	1·0-1·5
Al/Mg .	NS4	Rem.	0·15	1·75-2·75	0·75	0·60	0·5
Al/Mg .	NS5	Rem.	0·15	3-4	0·75	0·60	1·0
Al/Mg$_2$Si .	NSIO	Rem.	—	0·4-1·5	0·6	0·75-1·3	1·0
Al/Si	BS. 1490 LM-6-M	Rem.	0·10	0·10	0·6	10-13	0·5

Aluminium. This metal was first isolated by Wohler in 1845, but the principle of the modern electrolytic method of production from alumina dissolved in molten cryolite was not discovered until 1886 by Heroult in France and independently by Hall in America. Aluminium itself is produced in several qualities. Table Me II shows the composition of the commonly used qualities of aluminium and also of its better known alloys.

Table Me III gives the mechanical properties of these alloys and shows how the strength is altered by heat treatment. Some of these alloys are merely softened by annealing heat treatment, but in other cases remarkable increases in strength can be obtained whereby ultimate tensile strengths comparable with that of mild steel are produced. Of the cast alloys, probably the most important from the dairyman's point of view is LM-6—M (Alpax), which contains 10-13 per cent. silicon as the principal alloying element.

TABLE Me III

Metal		0·1 % *Proof Stress* (*ton/sq. in.*)	*Ultimate Tensile Strength* (*ton/sq. in.*)
SIB	Annealed	—	5·2
	Hard	7·8	9·4
SIC	Annealed	2·0	5·8
	Hard	8·5	10·0
NS3	Annealed	3·0	7·0
	Hard	11·0	13·0
NS4	Annealed	5·0	12·0
	Hard	16·5	18·0
NS5	Annealed	8·0	16·0
	½ hard	16·0	19·0
NSIO	Solution heat treated	6·5	13·5
	Solution heat treated and artificially aged	14·0	18·5

Ordinary purity (SIC) is the most commonly used sheet material, and it is easily fabricated by shaping, forming and joining operations. The most important of the latter is welding, which can be performed by the oxy-acetylene flame, the electric arc, or by the most modern process of the argon shielded arc (Fig. Me 2) in which no flux is used, thereby avoiding corrosion by flux residues which might occur when the older methods of welding are employed. For certain purposes it might be desirable to use purer aluminium such as SIA and SIB because of their higher corrosion resistance. The bulk of aluminium used in the dairy industry is for the following plant: Transport Tankers, Milk-Receiving and Storage Tanks, Churns, Cheese Vats and Aluminium cans used for condensed milk. Aluminium foil is used for lagging of transport tanks, for bottle caps and also for cheese wrapping, in which connections anodising is often employed to increase corrosion resistance by imparting a thicker oxide film to the surface (Alum. Devel. Assoc., 1948). Where strength is required in such items as milk churns, NS3 and NSIO are serviceable, and have been much used on the Continent of Europe. Examples of cast Alpax applications are Heat Exchanger plates, doors and fittings of storage vessels and many small dairy tools, such as spanners.

Aluminium causes no flavour defects in milk, though in highly acid products an unusual taste, described as metallic, may be produced (Hunziker *et al.*, 1929). The toxicity of aluminium, once seriously questioned, is now generally admitted

←Fig. Me 1—*Water Line Attack on Mild Steel*

Fig. Me 3—*Corrosion of Aluminium by Hard Water. Note Accumulation of Corrosion Product at Point of Attack* →

Fig. Me 2—*Welding by Argonarc Torch*

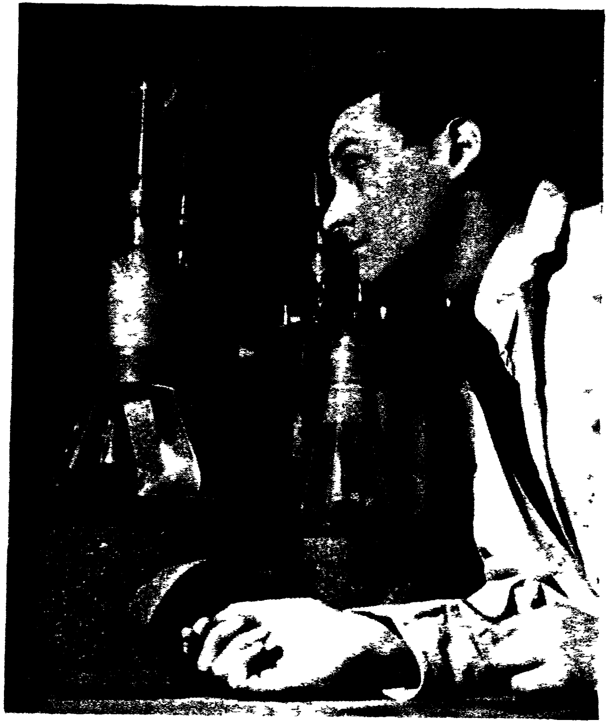


FIG Me 4.—*Apparatus for Corrosion Test in Completely Immersed Conditions*

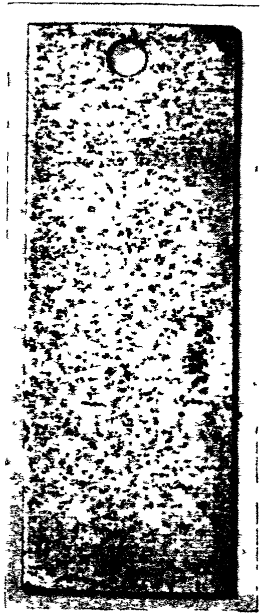


FIG Me 5.—*Pitting of* 18/8 *stainless Bychloride.*

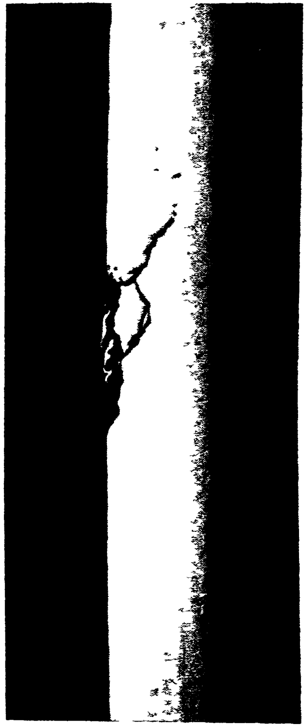


FIG. Me 6.—*Section through an* 18/8 *stainless steel Heat Exchanger Plate Stress cracked in Calcium Chloride Brine.*

to be non-existent (Burn, 1932; Underhill and Peterman, 1929); the hydroxide is, in fact, widely used as a remedy for digestive troubles.

Corrosion of Aluminium. Reference to the Electro-Chemical Series given later shows that aluminium should be a relatively reactive metal. However, the existence of a continuous film of aluminium oxide on its surface (Pilling and Bedworth, 1923) imparts an unexpected corrosion resistance. When this film is removed by scratching or other mechanical means, the metal is much more vulnerable, though damage is fairly quickly arrested by reformation of the oxide film when the corrodent is removed. The new film grows fairly quickly at first, but is probably not completely reformed for about 24 hr. General corrosion in which uniform attack takes place occurs when the oxide film is dissolved by alkalis or acids. On the other hand, pitting attack is localised and due to the corrodent penetrating the film at weak points, where corrosion proceeds directly below the points of penetration. The speed of general attack by alkali and acid increases with concentration and temperature, but there is one important exception to this rule in the case of acids. Strong nitric acid has little action on aluminium, therefore deposits from hard waters can be removed by this acid without harming the metal. If, however, the acid is diluted, its oxidising power decreases faster than its acidity, so that the hot 1 per cent. acid is quite seriously corrosive (see Table Me 4). Non-oxidising acids such as HCl and H_2SO_4 and some organic acids, such as lactic and citric, are corrosive in even very low dilutions. Strong alkalis, such as caustic soda, dissolve the metal rapidly. Tri-sodium phosphate and sodium carbonate also have appreciable action, but mixtures of sodium carbonate with sodium metasilicate have been used successfully for cleaning aluminium (Seligman and Williams, 1922).

Pitting of aluminium can be brought about in many ways. Cases of pitting in hard waters are of frequent occurrence (Seligman and Williams, 1920), and saline waters give the same trouble (Fig. Me 3). Pitting can also take place in slightly acid or alkaline conditions, but here other factors such as imperfections in the oxide film, supply of oxygen and temperature all may play a part. Unequal supply of oxygen to different parts of the same surface can also cause local attack, the phenomenon being known as " differential aeration " wherein the attack is confined to those places where the oxygen supply is too restricted to keep the film in good repair. The severe form of corrosion known as " water-line attack " may be due partially to differential aeration, but other explanations have been advanced here (Evans). A further serious form of corrosion frequently met and sometimes in not easily recognisable circumstances, is due to galvanic action between the aluminium and more noble metals such as nickel and particularly copper, when they are in contact in a solution. The copper may have originated from copper pipe lines not actually connected to the aluminium, and in cases of this sort an analysis of offending liquids for copper often gives informative results. This is especially true in the case of water supplies. The amount of attack in such cases depends on many factors, two of the most important being the electrical resistance of the solution concerned and the action which opposes the passage of corrosion current. This action is known as " polarisation ", and it is sometimes sufficiently complete to stop corrosion entirely. It is quite analogous to the polarisation of a primary electrical cell.

Useful prediction of the behaviour of a metal in a given corrosive environment can be obtained from laboratory testing where the most usual method is that of " complete immersion " in apparatus such as that shown in Fig. Me 4. The results of such tests are often expressed as " Solution Rate ", which is the weight loss in milligrams per square decimetre of surface per day. The test should also indicate if the attack is of a general or of a pitting nature. Only in the absence of pitting attack does the " solution rate " give a valid basis for prediction of the life of equipment. In U.S.A. it is more usual to convert " solution-rate " figures into inches loss of thickness per year of exposure, which may be easily effected by the formula:

$$\text{Solution rate} \times \frac{0{\cdot}00144}{\text{density of metal}} = \text{in. penetration per year of exposure.}$$

Provided the attack is general, a safe " solution rate " for aluminium for repeated treatments is about 10 when the loss of thickness figure is about $\frac{5}{1000}$ of an in. per year. This information is useful when chemical cleaning processes are being considered; in a process, for instance, of S.R. = 10 applied $\frac{1}{2}$ hr. per day, aluminium would lose $\frac{1}{1000}$ in. in 5 years. Typical "solution rates " of aluminium in boiling dilute acids and alkalis are:

TABLE Mc IV

1 % v/v HCl of S.G. 1·18	2475
1 % v/v H_2SO_4 of S.G. 1·84	2500
1 % v/v HNO_3 of S.G. 1·42	3250
1 % v/v H_3PO_4 of S.G. 1·50	200
1 % w/v NaOH	$>$ 5000
1 % w/v $Na_3PO_4 . 12H_2O$	1100
1 % w/v Na_2CO_3	2100
1 % w/v $Na_2SiO_3 . 5H_2O$	5

If a proposed cleaning technique is found to be prone to cause pitting, it should be discarded as pitting attack on aluminium is generally of much greater importance than solution rate in commercial practice.

Nickel. Nickel is a lustrous white metal very similar in appearance to silver. Its name is derived from Kupfer Nickel or Devil's Copper, a term applied by early German smelters who tried to produce copper from a mineral which was actually nickel arsenide. The metal was first isolated by Cronstedt in 1751, and is now produced in quantity in Europe and Canada, and it has many important uses in industry. However, the metal itself is not used extensively in dairy equipment largely because, in conditions where it does not suffer attack, other and cheaper materials are available. Nickel is suitable for cold milk contact, but with hot milk the rate of corrosion is high if protective films of protein are not formed. This is the case in regenerative pasteurisers where scale deposition is much greater in the heating sections than the cooling, so that the maximum corrosion of nickel would occur on surfaces in contact with hot pasteurised milk.

TABLE Me V

Metal	*Spec. BS. STA7*	*Ni %*	*Cu %*	*Fe %*	*Mn %*	*Zn %*	*Cr %*
Nickel	N.1	99·0 (min.)	—	0·2	—	—	—
Nickel Silver	N.S.3	14-16	60-65	0·3	0·5	Rem.	—
Cupro nickel	N.C.6	30 (min.)	Rem.	2·0		—	—
Monel	N.C.1	63-70	Rem.	2·5	2·0	—	—
Inconel	—	76	—	7·3	—	—	15

Nickel surfaces used for milk contact also tend to tarnish due to formation of nickel sulphide. Thin nickel sheet bonded to mild steel sheet and known as Nickel " Cladding ", and Nickel Plating are used to some extent in the dairy, but in general it is the alloys of nickel with chromium and iron, the stainless steels, which render the metal of such importance to the dairyman. Occasionally, the favourable thermal conductivity of nickel (*see* Table Me IX) is made use of as in the freezing barrel of one make of ice cream machine where a flash of chromium is used to impart erosion resistance. Alloys of copper and nickel, the cupronickels, and copper with nickel and zinc, the German silvers, are used to some extent. Another alloy, Inconel, was developed especially for dairy use. Chemical compositions are given in Table Me V.

Of these alloys, those containing copper have gradually fallen out of use in the dairy for equipment coming into contact with milk (*see* Copper). However, they are still used to advantage in items which present only small areas of contact. A typical example is the widespread use of nickel silver cock plugs which have the valuable property of suffering very little from seizing troubles. Monel and cupro nickel are always possible choices for equipment where mechanical strength and resistance to water and to the humid conditions in dairies, are required. Monel, for instance, is used for stirrer shafts, and also for the drum of flake ice machines. Inconel is resistant to milk and milk products. In its original form it had the reputation of losing its surface appearance and, in severe conditions of atmospheric exposure, could develop a green patina. It was used to some extent for contact with cooling brines, for any corrosion it suffered was reputed to be of a wide shallow pitting type compared with the deep pitting on stainless steel. Present day Inconel contains an extra 2 per cent. of chromium, and in consequence can be expected to give a better performance than the original alloy.

Corrosion of nickel. Nickel and its alloys are resistant to alkaline cleaning solutions, nickel itself being especially so. In oxidising conditions corrosion is usually accentuated so that dilute nitric acid and dilute solutions of phosphoric acid when aerated are too corrosive to be used for cleaning. This does not apply to Inconel, though it has been reported that the earlier alloy (containing 12-13 per cent. chromium) after heat treatment which might occur in welding was attacked by dilute nitric acid.

Stainless Steels. These are essentially alloys of iron and chromium in which the chromium content exceeds 12 per cent. They are newcomers compared with metals such as copper, tin and iron, as their commercial development has taken place largely during the past 50 years. Credit for their discovery appears to be due to at least six metallurgists—Guillet, Monartz, Giesin, Brearley, Portevin, and Maurer (Zappe, 1949), each of whom has good claims to be considered a pioneer in one class of these alloys. Nickel was an early addition to the basic iron-chromium alloy, and the discovery of the effect of nickel in producing the austenitic structure followed automatically. The stainless steels are usually

TABLE Me VI

Stainless Steel		*C*	*Cr*	*Ni*	*Mo*	*Ti*	*Mn* (*max.*)	*Al*	*Si* (*max.*)
BSI No.	*AISI No.*								
56A	403	0·10	13	—	—	—	1·0	—	1·0
—	440B	0·80	17	—	0·5	—	1·0	—	1·0
57	431	0·16	16·5	2·5	—	—	1·0	—	1·0
56AM	416	0·15	13	—	0·3	—	1·25	—	1·0
—	430	0·12	17	—	—	—	1·0	—	1·0
—	406	0·15	13	—	—	—	1·0	3·5-4·5	1·0
58A	302	0·12	18	8·5	—	—	2·0	—	1·0
58B	304	0·12	18	8·5	—	0·6	2·0	—	1·0
58E	312	0·05	18·5	10·0	—	—	2·0	—	1·0
58J	316	0·07	18	8·5	2·75	—	2·0	—	1·0

divided into three groups: (*a*) Martensitic, (*b*) Ferritic, and (*c*) Austenitic, to which the different structures give characteristic properties.

The Martensitic type is a straight iron-chromium alloy which is magnetic and which can be hardened by heat treatment. The ferritic type is also essentially an iron-chromium alloy of low carbon content. It is also magnetic, but not hardenable by heat treatment. The Austenitic steels are essentially iron-chromium-nickel alloys in which the chromium + nickel is at least 24 per cent., chromium a minimum of 16 per cent. and nickel a minimum of 8 per cent. The best known austenitic compositions contain 18 per cent. chromium + 8 per cent. nickel. These alloys are not magnetic, and are not hardenable by heat treatment, though they work-harden readily. Their corrosion resistance is high, and may be further improved for certain purposes by the addition of small amounts of elements, such as molybdenum, titanium, niobium, and copper. They are available in both wrought and cast forms, the machinability of the cast material often being improved by addition of such elements as sulphur, selenium, and tellurium which have little effect on corrosion resistance. The composition of typical steels is given in Table Mc VI.

Corrosion of Stainless Steel in the Dairy. " Stainless " is an unfortunate misnomer for these alloys, as the term has been understood popularly to mean they are entirely free from rust formation in moist air. While this is largely true of the 18/8 steels and particularly of those containing molybdenum, it is not true of steels such as 56A (Table Mc VI) containing only 13 per cent. chromium which do suffer rusting in continual exposure to moist atmospheres. The term " stainless ", therefore, is a comparative one, and is more truly denoted by " stain less ". Shirley and Truman (1948) have shown how composition affects resistance to rusting in industrial atmospheres. This rusting of stainless steel is unlikely to take place unless the surfaces remain untouched for considerable periods. Usually, simple wiping with a cloth is sufficient to disturb any surface condition which might lead to rusting. The high chemical resistance of stainless steel has also given rise to the erroneous impression that they are incorrodible. On the contrary, there are at least five main forms of corrosion which can affect these alloys:

(*a*) *Activation.* In this case, the steel is dissolved by uniform attack, hydrogen being produced. A general dulling of the surface occurs, leading to complete loss of polish and high solution rates. The chemicals most likely to gain entry into the dairy which might cause this attack are acid. Hydrochloric, sulphuric, and formic acid are activating chemicals, and even dilute nitric acid and phosphoric acid which do not normally attack stainless steel may do so if they are made up by using salty water for dilution.

(*b*) *Pitting.* In this form of corrosion, breakdown of the oxide film occurs only at isolated points and corrosion then proceeds inwards rather than laterally (Fig. Mc 5). Occasionally cases of covered pitting are met in which the surface may appear unaffected, but on probing is found to be deeply pitted under the surface skin. By far the most serious cause of pitting attack of stainless steel in the dairy is the chloride ion and the chemicals usually concerned are NaCl, $MgCl_2$, and $CaCl_2$ and hypochlorites. The effects are more certain if the chlorides are in slightly acid solution and can be offset to some extent by alkalis (*see* Brine and p. 691). One result of this sensitivity to the " acid-chloride " condition is that if milkstone deposits which contain chlorides from the milk are submitted to the action of acids such as dilute nitric or phosphoric, there is always a danger that the deposit will remain undisturbed sufficiently long to allow the chloride present with the acid to cause pitting attack. This will be especially severe at points in contact where crevice effects (*see* below) also take place. Hence it is good practice always to use alkali before acid when cleaning H.T.-S.T. plate pasteurisers or similar equipment. Hypochlorites contain much chloride and alkali and if used for short times in low dilution and at low temperatures (< 40° C.) will cause no attack because the action of the chloride is inhibited by the alkali

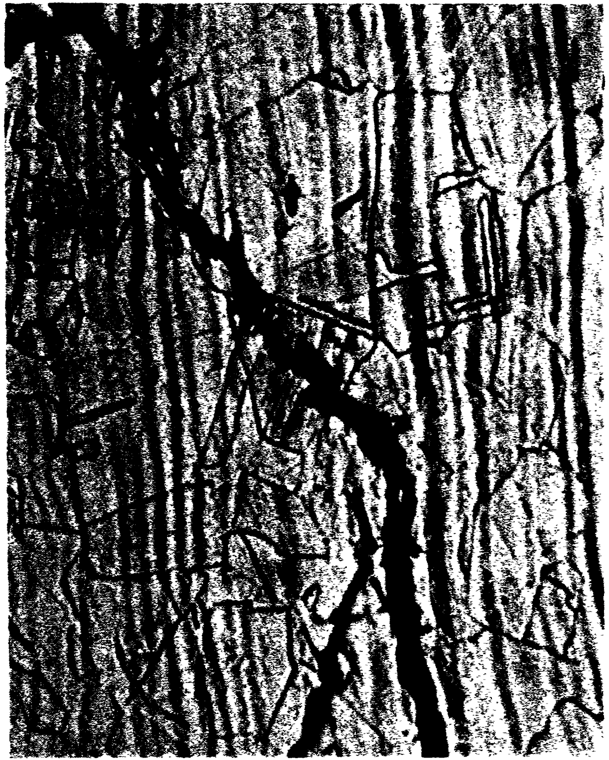


FIG. Me 7.—*Micrograph of Fig. Me 6 showing Stress Corrosion Crack Crossing a Grain (transgranular).*

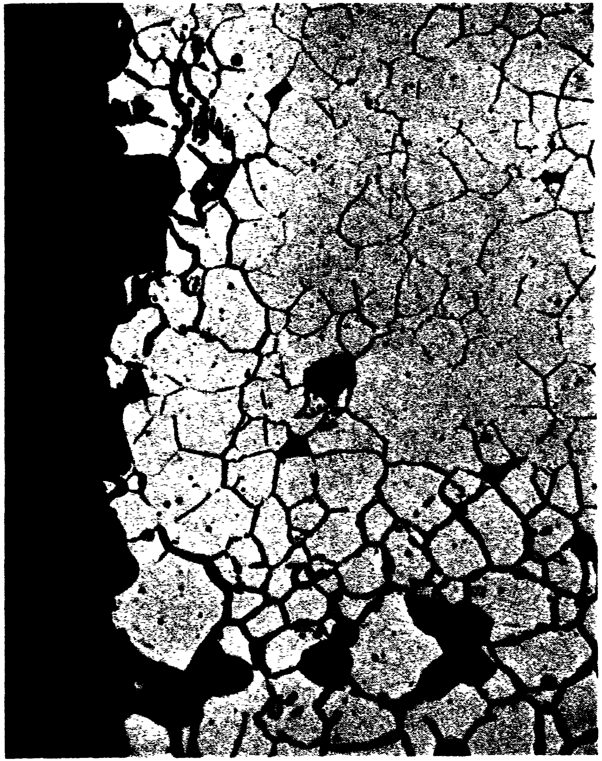


FIG. Me 8.—*Micrograph of Intergranular Corrosion of* 18/8 *Stainless Steel. Note how some Grains have fallen out of the Sheet.*

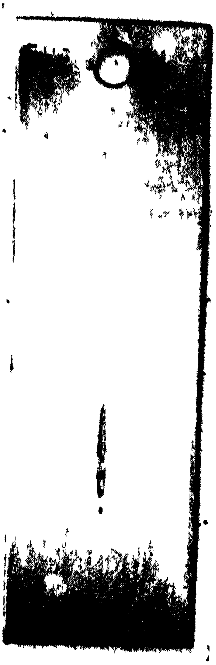


FIG Me 9 —*Crevice attack on Stainless Steel in Acid Calcium Chloride Brine*

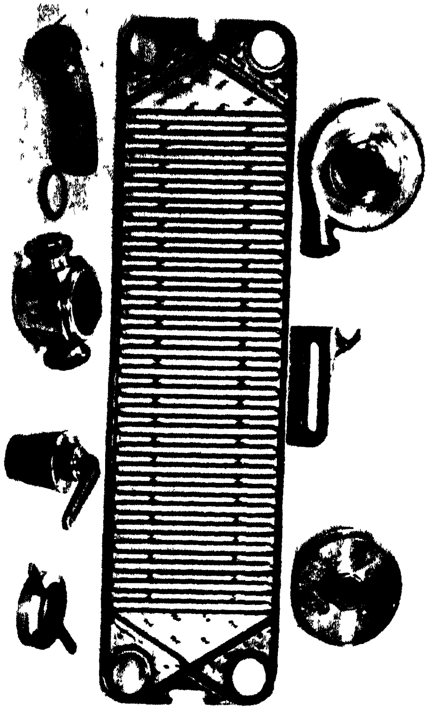
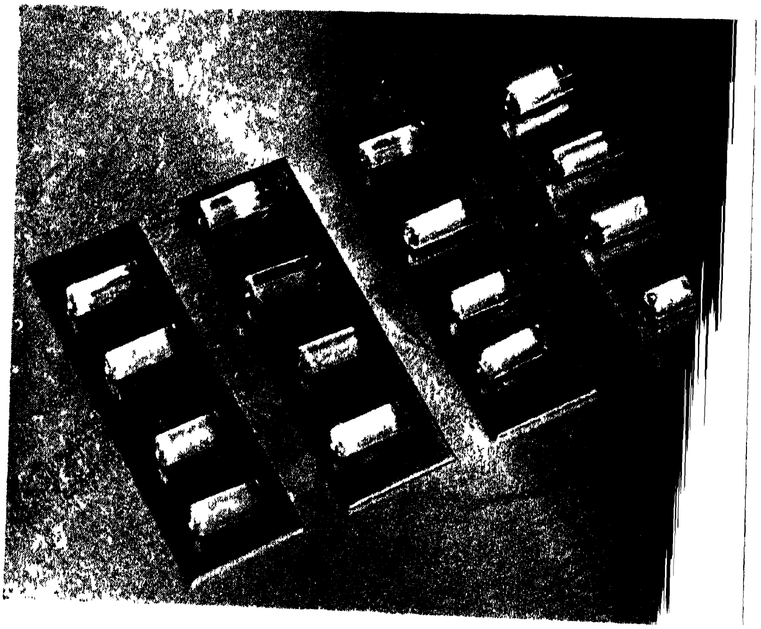


FIG Me 11 —*Cast and Wrought items in Stainless Steel for Dairy Plant*



(Botham and Dummett, 1949). If, however, hypochlorites are allowed to mix with acids, the mixture will pit stainless steel rapidly and with great severity (Botham, 1949).

Brine corrosion. Calcium chloride brine is the secondary refrigerant most widely used in the dairy. It is usually made up to about 20 per cent. strength from the commercial calcined salt which contains a little water-soluble calcium oxide giving therefore a solution definitely alkaline to indicators such as phenol phthalein. When this solution is exposed to air, which contains about 0·04 per cent. of carbon dioxide, the latter reacts with the calcium hydroxide and calcium carbonate is precipitated so that the alkalinity is gradually reduced, *i.e.* the *p*H falls. This action proceeds until an equilibrium point is reached which usually occurs about *p*H = 5·9, unless much iron is present when the equilibrium *p*H may be lower. As previously indicated, stainless steel is especially sensitive to chloride attack, but the action is minimised by (*a*) low temperature, (*b*) high *p*H, (*c*) the presence of molybdenum in the steel. Provided these conditions are observed, a steel containing 18 per cent. chromium, 8 per cent nickel, 3 per cent. molybdenum gives good service in calcium chloride brine. However, if the *p*H is allowed to fall below 8·3, as shown by the glass electrode, or the temperature of the brine is raised during sterilisation of plant, for instance, two types of corrosion may make their appearance: (*a*) pitting attack, as shown in Fig. Me 5 and/or (*b*) stress corrosion cracking, discussed later. In some cases the maintenance of *p*H and low temperature does not entirely prevent corrosion and here chromate inhibition has proved useful. Sufficient sodium dichromate followed by caustic soda is added to give about 0·15 per cent. w/v of sodium chromate in solution:

$$Na_2Cr_2O_7 + 2NaOH = 2Na_2CrO_4 + H_2O.$$

The chromated brine must still be maintained at a *p*H over 8·3, and more chromate must be added from time to time to make up losses. Usually an initial chromate content of 0·15 per cent. falls in a year to about 0·10 per cent., so that chromate strength must be checked from time to time. Although chromate is very beneficial as a corrosion inhibitor, its use has never become widespread in this country because it is poisonous and, moreover, may cause dermatitis. It should be noted, however, that in the event of a leak of chromated brine into milk, the latter would quickly become unpalatable because of the chloride content and it may be that the danger of toxic effects due to such mishaps has been overrated.

(*c*) ***Stress corrosion cracking.*** This takes place only if the steel contains high residual stresses through being heavily worked, and is submitted to the action of certain corrodents of which hot chloride solutions are the most potent. Of the chlorides, magnesium and calcium chloride are those most likely to be met in dairy work; sodium chloride is less prone to cause this form of attack. Corrosion appears to begin by forming a small pit, at the apex of which, stress concentration takes place. After a certain and unpredictable time a crack starts from this apex, and corrosion is then concentrated at the end of the crack leading to further weakening of the steel In such cases very little pitting of the surface may be noted, but on sharp impact the steel crazes into a network of branching cracks. Fig. Me 6 shows a section of a Heat Exchanger plate stress cracked in calcium chloride brine, and Fig. Me 7 is a micrograph of the same plate showing how cracks proceed both intergranularly and also transgranularly, Fortunately this type of corrosion is comparatively rare.

(*d*) ***Intergranular attack*** (***weld decay***). This form of corrosion is met infrequently at the present time, though in the form of weld decay it caused great trouble some years ago. When a stainless steel containing about 0·12 per cent. carbon is heated in the temperature range 500° to 900° C., some of the chromium at the grain boundaries is immobilised by formation of chromium carbide, so these boundaries become more prone to corrosion than the rest of the steel and attack follows the intergranular boundaries. During welding only small zones some distance from each side of the weld remain in the sensitising temperature range for a sufficiently long time to produce carbide formation. Hence, weld decay is a localised form of intergranular attack running parallel with the weld. Modern practice is to add titanium or niobium to steels which are to be welded, for these elements combine preferentially with carbon, thus preventing denudation of chromium at grain boundaries. A more recent method is to reduce the carbon content to about 0·02 per cent., but this is very costly. Fig. Me 8 is a micrograph of a sensitised stainless steel attacked intergranularly; in some areas the grains have actually fallen out of the metal.

(*e*) ***Crevice attack.***—This form of corrosion occurs on parts of stainless steel surfaces on which foreign matter is allowed to remain for some time, and is due essentially to the fact that such points become more sensitive to attack than the remainder of the surface because they are screened from oxygen. Fig. Me 9 shows a test piece to which a piece of glass rod was attached before being immersed in calcium chloride brine. The only attack is where the rod has touched, three quite deep pits being produced. Pitting attack by calcium chloride brine in practice may be enhanced by this effect which may obtain because of calcium carbonate and rust deposits on the steel. Fig. Me 10 shows an arrangement used in the laboratory to compare the resistance of different steels to this form of corrosion.

Corrosion by milk and its products. The 18/8 class of austenitic stainless steel used for milk contact suffers no attack in practical conditions usually employed. No metallic ions are given up to the milk to cause flavours, though acid creams have been suspect in this connection. Sour milk which contains both salt and lactic acid may, if left to stand in contact with stainless steel for several days, cause pitting for here we have the acid chloride and crevice condition present together.

General theories on corrosion resistance of stainless steel. Stainless steel is thought to owe its high corrosion resistance to a thin oxide film on its surface. The existence of such films has been demonstrated (Vernon *et al.*, 1944*a*), and analyses of them have been carried out (Vernon *et al.*, 1944*b*). The present view of the adherents of the film theory is that when corrosion takes place by activation the oxide is entirely removed, whereas pitting takes place by penetration of the film by corrosive ions at weak places. Where no corrosion occurs the oxide film maintains the passive state and the theory receives support by many practical observations based on the proved effect of oxygen and oxidising agents in maintaining and sometimes restoring passivity, *e.g.* the addition of chromates to brines. Reducing agents, as might be expected, tend to destroy passivity. There are, however, at least two alternative schools of thought. One attributes the phenomenon of passivity to a physical arrangement of the electrons of chromium and nickel atoms (Uhlig, 1944), while the other adduces evidence in support of the idea that passivity is due to a film of gas adsorbed on the surface of the steel. The gas may even be inert such as argon (Fontana and Beck 1947).

Fig. Me 11 shows examples of cast and wrought sheet items in stainless steel in dairy plant.

Copper and Tin. Copper and its alloys have fallen out of favour in the dairy in recent years, whereas formerly their high thermal conductivity and the ease with which copper can be fabricated led to their widespread use. It should be noted, however, that for actual milk contact only small areas of copper or its alloys could be used because minute traces of dissolved copper give rise to tallowy or oily flavours. Various figures have been given for the copper content below which " oxidised " flavours will not be developed, but 1·5 p.p.m. seems a safe assumption (Davies, 1941), and it is significantly higher than the normal figure of 0·2 to 0·4 p.p.m. for pasteurised and bottled milk.

The role of copper appears to be essentially that of a catalyst in the oxidation of the unsaturated fatty acid radicals of the triglycerides of butterfat. Dissolved copper is also said to cause serious reduction of the vitamin C content of milk. Cheese, on the other hand, appears to be able to tolerate much more copper without suffering from flavour defects. For the above reason, tinned copper and tinned-copper alloys such as gunmetal for wrought, cast and machined items have been used for dairy equipment of many sorts and the combination has given good service provided non-porous coatings of tin of about 0·002 in. thick were used. Tin has no effect on the flavour of dairy products, but it is relatively soft, is alkali and acid soluble and not so easy to keep clean as stainless steel.

TABLE Me VII

Metal	*BS. STA7*	*Cu* %	*Sn* %	*Pb* %	*Fe* %	*Ni* %	*P* %	*As* %	*Al* %	*Zn* %
Copper (tough pitch)	C.1	99·75	0·03	0·02	0·02	0·15	—	0·05	—	—
Copper (deoxidised)	C.2	99·75	0·03	0·02	0·05	0·15	0·015	0·05	—	—
Copper (arsenical) .	C.11	99·20	0·01	0·01	0·03	0·15	0·02-0·08	0·3-0·5	—	—
Al Bronze .	C.A.1	Rem	—	—	0·5	—	—	—	4·0-6·0	
Gunmetal .	C.G.3	Rem.	7·5-8·5	0·5 (max.)	—	—	—	—	—	3·5-4·5
Brass (naval)	C.Z.8	62	1·0	—	—	—	—	—	—	37

TABLE Me VIII

Solution Rate of Alkalis on Copper and Gunmetal at 80° C.

A = No sulphite. B = + 1 % w/v Na_2SO_3

Metal	1 % *$NaOH$*		1 % *Na_2CO_3*		1 % *$Na_3PO_4 . 12H_2O$*		1 % *$Na_2SiO_3 . 5H_2O$*	
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*
Copper . .	70	10	74	7	91	5	24	3
Gunmetal .	88	9	38	7	72	6	63	2

Solution in alkali can be reduced to a great extent by using sodium sulphite with the alkali whereby the solution rate of tin can be reduced by 90 per cent. (Kerr, 1935). Copper and its alloys are still used for parts not exposed to milk. They have good resistance to waters other than upland surface waters which when hot can be aggressive. The greatest single use of copper, however, throughout the industry is now for the transmission of electricity. Alloys (for composition *see* Table Me VII), such as gunmetals, aluminium, bronze and the brasses are still met occasionally in parts such as pump impellers, cocks and valves.

Corrosion of copper and tin. *Acids.* Oxidising acids such as nitric acid are very destructive to these metals. Even phosphoric acid, which when free from air gives low solution rates, becomes much more corrosive when aerated:

SOLUTION RATES IN 2 PER CENT. PHOSPHORIC ACID AT 180° F.

	Copper	*Tin*
Unaerated . . .	134	67
Aerated . . .	4000	288

Alkalis. Hot alkalis of strengths used for cleaning in dairies have appreciable action on copper and tin, the effect being increased by aeration and greatly reduced by removal of dissolved oxygen by means of sulphite (Table Me VIII). Ammonia and ammonium salts are very corrosive, even in low concentration to copper alloys.

Zinc. This metal provides another example where use in the dairy is restricted to coatings for items in mild steel and iron. Its resistance to dilute acids and alkalis is poor, and it is not used for milk contact. Its toxic effect has often been debated, and it has been reported to give rise to bitter metallic taste in milk in concentrations as low as 17 p.p.m. (Donauer, 1922).

Zinc coatings are applied by Hot Dipping, Spraying, Electrodeposition, Sherardising, etc. In the first method, that most generally used, substantial coatings of 2 oz. per sq. ft. are produced, and these are free from porosity. A section through a hot dip galvanised coating shows that there is a gradual transition from the iron through iron-zinc alloys of varying composition to the zinc itself. The alloy layers account for about one-third of the total thicknesses, so the two metals are actually chemically united and the coating cannot peel.

The protection afforded by zinc is of a dual nature. In the first place, the continuous coat protects the steel mechanically. The second line of defence depends on the fact that in solutions which corrode steel (water containing dissolved oxygen is a good example) the zinc is preferentially attacked and corrodes sacrificially, thus protecting the iron even if some parts of the latter have been denuded of zinc. This protective action derives fundamentally from the relative position of the two metals in the Electrochemical Series.

ELECTROCHEMICAL SERIES OF METALS

Metal	*Normal electrode Potential Volts*	*Metal*	*Normal electrode Potential Volts*
Gold . .	+ 1·420	Iron	− 0·440
Silver . .	+ 0·800	Chromium	0·710
Copper . .	+ 0·345	Zinc	0·762
Lead . .	− 0·126	Aluminium	− 1·670
Tin . .	− 0·136	Magnesium	2·340
Nickel . .	− 0·250	Sodium	− 2·712
Cadmium .	− 0·402	Lithium	− 3·020

The most reactive metals such as sodium are at one end of the series while the noble metals such as gold and silver are at the other. The relative position of any two metals in the series indicates which will be the more electrically positive when they are in contact in a conducting solution; in more accurate terms, which has the smaller tendency to lose electrons, the units of negative electrical charge.

Consider the case of iron and zinc immersed in a simple conducting solution and connected externally by a wire (Fig. Me 12). The zinc tends to lose electrons via the wire to the iron and positively charged ions of zinc tend to pass into solution. The supply of electrons received by the iron opposes the loss of iron ions to the solution so the iron remains at a higher electrical level or potential than the zinc. The flow of current is due to this movement of electrons, and it will be noted it is in the opposite direction to the flow of current as it would be shown by an ammeter connected in the external circuit between the two poles.

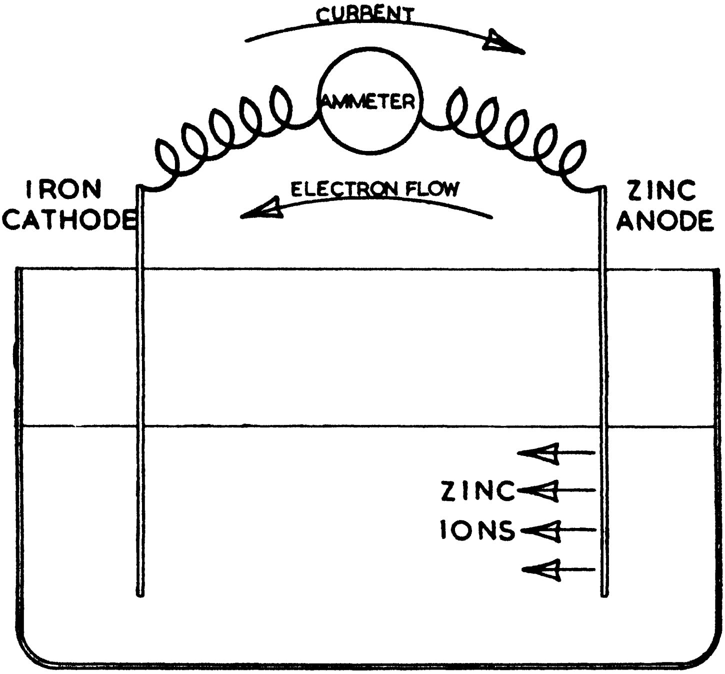


FIG. Me 12.—*Iron and Zinc Immersed in a Simple Conducting Solution and Connected Externally by a Wire.*

The protective effect of zinc for iron is an illustration of the general principles of electrochemical corrosion and of the practical results of contact between dissimilar metals in solutions which conduct electricity. In such cases the more negative or less noble metal corrodes more quickly than if the contact is not present and in so doing, protects the more noble metal. The phenomenon is put to good use in galvanising of steel, but the reverse of the picture is the enhanced corrosion when the effect is accidental. Accidental coupling of copper and aluminium, for instance, can cause serious attack on the latter, and it will be obvious from the foregoing that tin or nickel coatings on steel can only have a mechanically protective action. If such coatings are porous, the iron will corrode rapidly at such weak points; if they are very small the corrosion may proceed to a significant depth before being noticed. Cases are known of zinc becoming noble to the iron it was designed to protect, with the inevitable result of pitting of the iron. This is now clearly recognised as a possibility in some waters at temperatures of 65° C. and over, in which conditions the zinc corrosion product films prevent further zinc from going into solution and the electron flow is reversed, allowing iron to be dissolved (Gilbert, 1948).

The above examples of electrochemical corrosion are special cases. But corrosion of a single metal follows precisely the same course because no metal is homogeneous. Its surface is composed of an infinite number of points, some of which are at a lower electrical potential than their neighbours when immersed in an aqueous solution. These points lose electrons to the surrounding areas, so an enormous number of local electrical cells is produced, the corroding points being the *anodes* and the protected points the *cathodes*. The analogy between these terms in electrochemical corrosion and in electrolysis will be made clear by Figs. Me 13 and Me 14. It should be noted that in both cases the *anode* is the pole losing metal to the solution. The fact that in corrosion the *anode* is the negative pole and in electrolysis it is the positive should not be confusing when it is realised that in corrosion processes the electrical energy is produced by the system itself, while in electrolysis the electrical energy is applied from an external source, the direction of electron flow being from anode to cathode outside the solution in both cases. The production of hydrogen and alkali at the cathode opposes the corrosion current, so that the cell tends to polarise and corrosion rate diminishes. Dissolved oxygen in solution removes the cathodic hydrogen, and acids neutralise the alkali as soon as it is formed. This action explains the effects of aeration on, for example, the corrosion rate of phosphoric acid on nickel

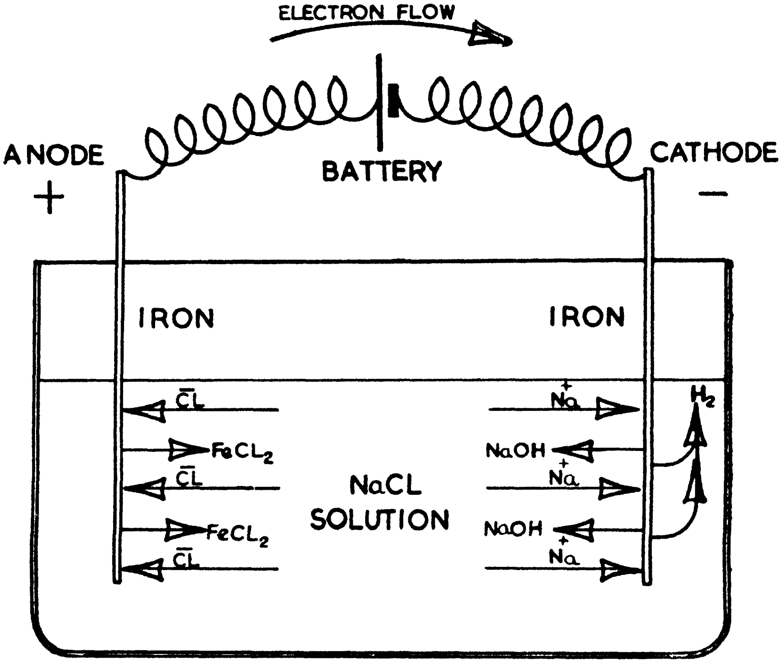


FIG. Me 13.—*Electrolysis Reactions.*

1. Na^+ to cathode; Cl^- to anode.
2. *At cathode.*
(*a*) $2\ Na^+ + 2e = 2\ Na$
(*b*) $2\ Na + 2H\ .\ OH = 2NaOH + 2H$
(*c*) $H + H = H_2$

At anode.
(*a*) $2\ Cl^- - 2e = 2Cl$
(*b*) $2\ Cl + Fe = FeCl_2$
3. *Anode and cathode products reacting.*
$FeCl_2 + 2NaOH = Fe(OH)_2 + 2NaCl$
$Fe(OH)_2 +$ dissolved oxygen $\rightarrow$
$Fe_2O_3\ .\ H_2O$ (rust)

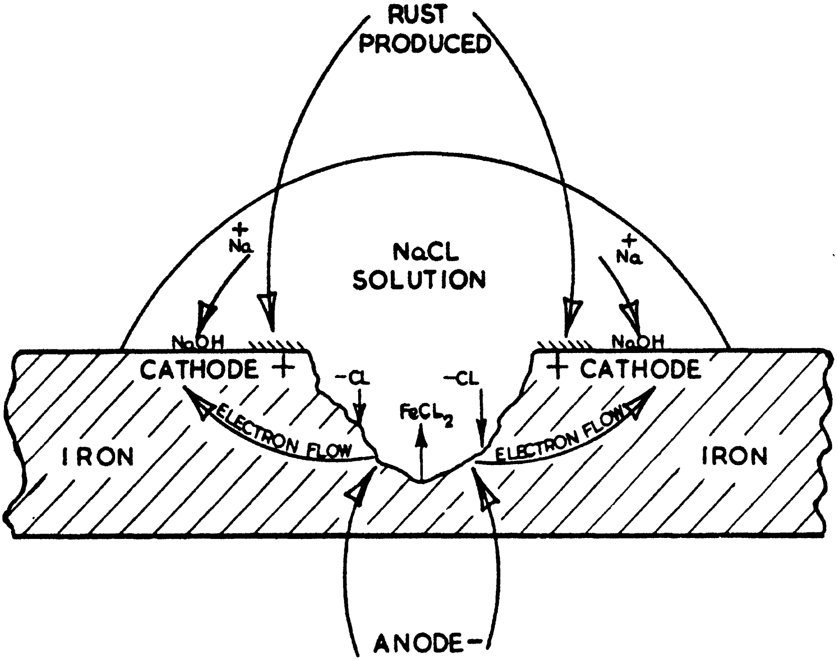


FIG. Mc 14.—*Electrolytic Corrosion.*

TABLE Mc IX

PHYSICAL PROPERTIES OF COMMON METALS AND ALLOYS

	Specific gravity	*Melting point* °C.	*Thermal conductivity* (c.g.s.)	*Specific heat* (c.g.s.)	*Coefficient thermal expansion per °C.* ($\times 10^{-6}$)
Aluminium	2·70	660	0·570	0·211	23·5
Copper	8·92	1084	0·920	0·093	16·4
Iron	7·87	1535	0·174	0·109	12·3
Nickel	8·91	1455	0·140	0·109	13·0
Tin	7·30	232	0·147	0·056	23·0
Zinc	7·14	420	0·265	0·094	31·2
18/8 S.S.	7·90	1430*	0·038	0·120	16·0
Steel (0·25 % C.)	7·86	1500*	0·124	0·116	12·2
Al/Mn (NS3)	2·74	654*	0·430	0·230	23·0
Al/Si (LM-6-M) (11·7 % Si)	2·65	577*	0·340	0·230	20·0
Naval Brass	8·41	890*	0·260	0·090	21·2
Nickel Silver (15 % Ni)	8·65	1060*	0·072	0·090	16·2
Monel	8·83	1350*	0·062	0·127	14·0
Inconel	8·51	1425*	0·036	0·109	11·5

* Liquidus temperature.

and also why salt solutions such as chlorides are generally much more active when *p*H is lower than 7.

Refs.: Bain (1941), *Functions of the Alloying Elements of Steel*, The American Society for Metals; Rolfe (1942), *Steels for the User* (Chapman & Hall, Ltd.); Aluminium Development Association (1948), Information Bulletin No. 14; Hunziker, Cordes, and Nissen (1929), *JDS*, **12**, 140; Burn (1932), *Aluminium and Food*, B.N.F.M.R.A. Research Reports External Series, No. 162; Underhill and Peterman (1929), *Amer. J. Physiology*, **90**, 40; Pilling and Bedworth (1923), *J. Inst. Met.*, **29**, 529; Seligman and Williams (1922), *J. Inst. Met.*, **28**, 297; Seligman and Williams (1920), *J. Inst. Met.*, **23**, 1, 159; Evans (1948), *An Introduction to Metallic Corrosion* (Edward Arnold & Co.), p. 135; Zapffe (1949), *Stainless Steels*, The American Society for Metals, p. 13; Shirley and Truman (1948), *J. Iron and Steel Inst.*, **160**, iv, 367; Botham and Dummett (1949), *JDR*, **16**, 1, 23; Botham (1949), XIIth International Dairy Congress, Section III*a*, p. 310; Vernon, Wormwell and Nurse (1944*a*), *Metallurgia*, **31**, 19; Vernon, Wormwell, and Nurse (1944*b*), *J. Iron and Steel Inst.*, **150**, 81P; Uhlig (1944), *Trans. Electrochem. Soc.*, **85**, 307; Fontana and Beck (1947), *Metal Progress*, **51**, 939; Davies (1941), *JDR*, **3**, 90, 31; Kerr (1935) Tech. Pub. No. 19, Series A, International Tin Research and Development Council; Donauer (1922), *Ice Cream Review*; Gilbert (1948), *Sheet Metal Industries*, **25**, 2003, 2243, 2441.

METALLIC CONTAMINANTS IN FOOD.

Refs.: Monier-Williams (1949), *Trace Elements in Food*, London; Richmond; Cox; Allport and Garratt (1948), *JSCI*, **67**, 382 (estimation); Monier-Williams, *ibid.*, 387 (public health aspects); Forstner (1948), *CI*, 499 (occurrence); *Soc. Publ. Anal.* (1934), "Bibliography of the More Important Heavy Metals Occurring in Food and Biological Material". *See* Trace elements.

METALS IN MILK. Milk as secreted by the cow contains negligible amounts of the heavy metals, iron, copper, etc., but in handling and processing variable but small amounts may dissolve in the milk, chiefly through the dissolving of the oxides present on the surface of metal containers, etc., through corrosion by the acidic substances in the milk. Of these copper is easily the most important as very small amounts, *e.g.* 1 to 3 p.p.m. may produce oiliness (p. 774) and oxidised flavours (*see* Taints and Flavours). Iron is also commonly taken up by milk but it requires 10 to 20 p.p.m. to produce off-flavours in milk. *See* Nutritive value; Vitamins.

Ref.: Davies.

METHYL RED TEST. *See* Coliforms.

METHYLENE BLUE TEST. General. The fundamental difference between the M.B. test and the plate-count is that the former measures the chemical activities of the micro-organisms in the milk and the latter the number of colonies which grow from cells or cell-clumps in a solid nutrient medium.

The three most important factors controlling the reduction of the methylene blue are: (1) the oxygen dissolved in the milk; (2) reducing systems in the milk; and (3) the reducing activity of the micro-organisms. When only a few bacteria are present (1) is predominant; with many bacteria (3) becomes the most potent factor and the methylene blue is reduced. In the absence of oxygen (2) can reduce methylene blue in an hour or so, but under practical conditions can be ignored. The oxygen content of milk is about 25 times the equivalent of the methylene blue in the oxidised form. Most of the activity of the bacteria is, therefore, spent in removing this oxygen by respiration, the methylene blue not being reduced until all the oxygen is consumed.

The modified method introduced by Wilson, although involving a little extra trouble (half-hourly inversion of the tubes), results in a shorter reduction time (about three-quarters of the former time) and, more important, in much greater accuracy. The fat globules to which are attached bacterial clumps formerly rose to the surface, but are now kept evenly distributed by the regular inversion.

Of the specific advantages of the M.B. test over the plate-count method, the most important is the accuracy or reproducibility of results. The coefficient of variation of the plate-count is about 20 per cent. (considered arithmetically), whereas that of the M.B. test is only 1 to 2 per cent.

The point next in importance is that while the plate-count is a measure of *numbers* of cells, or cell clumps, the M.B. time is a measure of *activity*. Thus growth in the lag phase, in which cells increase in size but not in numbers, is reflected in the M.B. test but not in the plate-count.

Further, clumping has no effect on the M.B. test, but has a drastic effect on the plate-count.

The difference in cost between the plate-count and the M.B. test may be considerable when a large number of samples are collected at one place, as in depot sampling. Usually, however, the cost of taking and transporting the sample is higher than that of doing the test. The saving in total cost of a M.B. test compared with a plate-count may, therefore, become barely significant when samples have to be collected from farms.

One important advantage is the quickness with which a result is obtained, *viz.* in only about 6 hr. from the receipt of the sample, compared with 48 hr. for the plate-count.

One advantage that has been claimed for the methylene blue test is that it can be performed by unskilled labour. This is fundamentally unsound. No scientific control work, whether chemical, bacteriological, or in any other field, should be carried out without the immediate supervision of a properly trained worker.

The disadvantages of the M.B. test are as follows: First, it is unsuitable for freshly pasteurised milk. Further, it requires 5 to 6 hr. continuous attention in the laboratory. In the plate-count method the milk is plated, the plates incubated and left until examined after 48 hr. No attention is required between putting the plates away in the incubator and taking them out for counting.

The plate-count in the hands of an experienced person, reveals the types of organisms present, *e.g.* spore formers, coloured cocci, mastitis streptococci, and other types giving well-defined colonies. Such information may give a valuable clue to the tracking down of a specific fault in bad methods of production. Thus on one occasion when very poor keeping quality was experienced, the plate-count revealed a very high count of coloured cocci in almost pure culture. Unsterile utensils were suspected and it was found, in fact, that bottles were not receiving proper cleansing and so were infecting the milk with enormous numbers of these particular micro-organisms. Similarly, an unduly high count of aerobic spore formers indicates that gross air contamination by cereals or other materials rich in spore-forming organisms may be taking place.

Fluctuation in keeping quality and count when methods of production are beyond criticism may be due to outbreaks of mastitis. In cases of considerable infection in a herd, milk agar plates will reveal the typical small translucent streptococcus colonies. Milk from mastitis-infected cows usually has a considerably higher count than milk from uninfected cows. An appreciable incidence of mastitis will therefore seriously affect the keeping quality of the bulk milk of a herd. The plate-count in many cases will reveal the cause of this, but the methylene blue test usually fails to do so.

Mastitis streptococci are peculiar in failing to reduce methylene blue; it is in fact inhibitory to them. It follows, therefore, that milk may contain large numbers of mastitis streptococci and yet give a long reduction time. The very rapid reduction of methylene blue by milk from cows badly infected with mastitis is due to an entirely different cause. This type of reduction is brought about by leucocytes (white blood cells) and is usually not complete, although in some cases almost instantaneous. The pale blue colour may remain for hours, but often the full colour returns on inversion. This phenomenon is invariably correlated with a high catalase figure.

A general criticism of the methylene blue test has been that it is too severe in summer and of little use in winter. In other words, poor methods of production may " get away with it " in winter and a good producer may be penalised in summer. This state of affairs is not so much a criticism of the statutory reduction times of 4½ hr. in summer and 5½ in winter as of the methods of treating the samples. Indeed it is a general criticism of all bacteriological tests, whether of milk or any other material : that unless the methods of treating the sample (*i.e.* time and temperature of holding) are controlled, the result is of little value.

The Methylene Blue Reduction Test (Wilson *et al.*; Stat. Instr. Nos. 1589 and 1590 (1949). *Apparatus required:* (i) Water-bath at 37·5 ± 0·5° C. thermostatically controlled and containing perforated plates to hold test-tubes. (ii) Test-tubes 6 × ⅝ in. (B.S.I. Specification No. 625) etched at 10 ml. (iii) Rubber bungs to fit these test-tubes. (iv) Methylene blue tablets (B.D.H.). (v) 500 ml. graduated cylinders. (vi) 1000 ml. conical flasks.

Preparation of methylene blue solution. Dissolve one tablet in 200 ml. of cold sterile glass-distilled water in the litre flask. Add a further 600 ml. and store in a cool, dark place. As this solution is quite cheap and may allow bacteria to proliferate, it is recommended that a fresh solution be prepared every week.

Treatment of tubes and bungs. Tubes and bungs should be thoroughly cleaned and the tubes placed upside-down in a wire basket, the bungs in a metal container with a little water, and both sterilised in the steam chest or autoclave. They should be left in the chest until used.

Technique. Transfer milk from each churn with a sterile dipper or pipette to the test-tubes, filling up to the mark. One dipper, kept in boiling water and drained before use, may be used in the absence of properly sterilised dippers. Add 1 ml. of the methylene blue solution, insert the bung (holding it only at the upper edges) and mix by inversion. Place (bung upwards) in one of the holes of the test-tube rack in the water-bath at 37·5° C. Examine every ½ hr., inverting and reverting unless reduction has begun.

Water-bath. This must be dark (when closed) and the temperature accurately controlled so that it remains at 37·5° ± 0·5° C. The capacity of the bath must be such that an excessively long time is not required to recover the temperature after the introduction of a large number of tubes. As a rough test the maximum number of tubes may be introduced when the temperature is 37·5° C. If the temperature has not recovered to 37° C. in 10 min., the bath may be considered to be at fault. The holes to receive the tubes should be of the size to hold comfortably the standard tubes, and should be arranged and numbered in tens.

Treatment of samples. When shaking the bottle as directed, the elbow may conveniently be placed on a pad or duster on the bench. The methylene blue solution should be added *after* the milk, as otherwise the dye may be adsorbed on films on the glassware, and so result in a low concentration of dye in the milk.

Controls. It is advisable to put up two sets of controls, one in the bath and one outside. Should the control in the bath then be reduced (as sometimes happens) the other may be used. Controls are prepared with 10 ml. of mixed milk and 1 ml. of tap water, and 10 ml. milk and 1 ml. of methylene blue solution. They should be boiled for 3 min.

Separate controls must be used for the Channel Island breeds, as the resulting colour is quite different from that given by milk containing less pigment.

Examination of tubes. Tubes should always be compared with the controls against a white card illuminated by a shaded daylight lamp. The lamp must be protected by a shade so that no direct light falls in the eyes of the observer.

Inversion of tubes. Although some baths are fitted with invertible racks, it is advisable to examine and invert each tube separately, reverting before replacing in the bath.

I. *Raw milk.* The methylene blue test is the official test for tuberculin-tested milk and accredited milk, and more recently for pasteurised milk and ice cream. It is unusual to find milk which has passed either the plate-count test (count less than 200,000 per ml.) or methylene blue test (reduction time greater than 4½ hr. in summer, 5½ hr. in winter) to be a source of trouble in processing or food manufacture. If bad faults persist, however, when the milk has passed one of these tests, examination must be made for specific types of fault-producing organisms. The most common are the *coli-aerogenes* bacteria and the *butyric acid* bacteria. Relatively simple tests for the presence of these organisms can be applied (*see* pp. 262 and 157).

II. *Pasteurised milk.* The technique of the test is identical with that for raw milk but the sample is held at atmospheric shade temperature (not exceeding 65° F.) until 9 to 10 a.m. on the following day and then tested. If the milk reduces the dye in ½ hr. it fails the test. This modification is commonly referred to as "the half-hour methylene blue test". *See* Bacteriological equivalents; Bacteriological grading; Ice cream; Legal aspects; Pasteurisation; Plate count; Resazurin.

Refs.: I. *Raw Milk.* Wilson *et al.*; Barkworth and Hosking (1952), *SAB*, **15**, 116; Garvie and Rowlands (1952), *JDR*, **19**, 133, 263; Stat. Instr. No. 1590 (1949); Garvie (1952), Ph.D. thesis, Reading; Hunter (1949), *JDR*, **16**, 149 (penicillin effect); Barkworth, Irwin and Mattick (1941), *JDR*, **12**, 265; Matuszewski and Supinska (1940), *JDR*, **11**, 43 (different techniques); Hobbs (1939), *JDR*, **10**, 35 (role of bacteria); Chalmers (1938), *JDR*, **9**, 351 (as a measure of keeping quality); Nichols and Edwards (1936), *JDR*, **7**, 258 (comparison with plate count); Jackson (1936), *JDR*, **7**, 31 (factors in reduction of methylene blue); *Milk Testing*.

II. *Pasteurised milk.* Stat. Instr. No. 1589 (1949); McKenzie (1947), *DI*, **12**, 764; Davis and Watson (1946), *SAB*, p. 81 (comparison with other tests); Watson *et al.* (1946), *SAB*, p. 56 (reproducibility); McKenzie and Booth (1945), *SAB*, p. 31; Rowlands and Provan (1944), *SAB*, p. 22. *See also* Ice Cream.

METHYL n-AMYL, METHYL n-HEPTYL, AND METHYL n-NONYL KETONE. These ketones are produced by moulds of the *P. roqueforti* type and are considered to be constituents of the Roquefort cheese flavour (p. 199). The flavour sometimes occurs in mouldy butter. The ketones are presumably derived from the corresponding fatty acid.

Ref.: Davies.

METRE. 39·37 in. or 3·28 ft.

METRIC UNITS. *See* Weights and measures.

MICELLE, MICELLA. A structural unit or particle of a colloid.

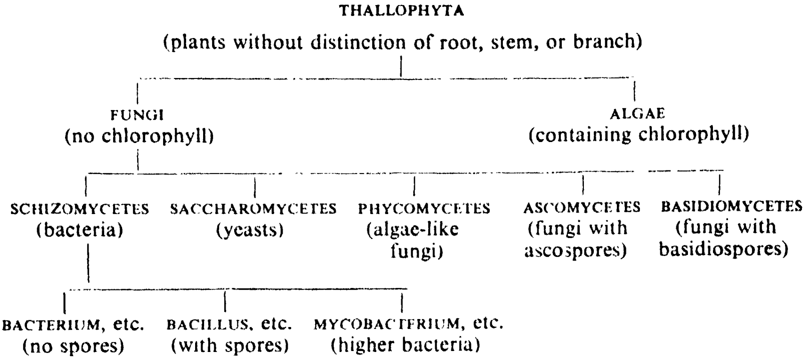
MICROBACTERIUM. The name given by Orla-Jensen to a genus of Gram positive, catalase positive, non-spore forming, heat-resistant rods with weak saccharolytic properties. Some workers consider it to be identical with *Corynebacterium*; alternatively it may be considered to be a closely related genus. *See* Classification; Thermoduric bacteria.

Refs.: Bergey; Orla-Jensen; Orla-Jensen (*LAB*); Abd-el-Malek and Gibson (1952), *JDR*, **19**, 153.

MICROCOCCUS. This word is used in two senses: (i) as a general term for a small coccus (micrococcus); (ii) as the name of a genus of cocci (*Micrococcus*) some species of which have large cells. *See* Classification.

Refs.: Bergey; Wilson and Miles; Abd-el-Malek and Gibson (1948), *JDR*, **15**, 249 (micrococci in milk); Shaw *et al.* (1951), *JGM*, **5**, 1010.

MICRO-ORGANISMS, CLASSIFICATION OF. The term " micro-organism " usually includes bacteria, yeasts, and moulds, and these may be considered as the lowest or most primitive forms of plant life. Their general relationship may be written as follows :



See Classification ; Moulds.

MICROSCOPE. This is used far less in dairy bacteriology than is generally supposed, because simple indirect or plating methods are almost universally used for the enumeration of micro-organisms. It is essential for the direct microscopic count (below) and for identification of types of micro-organisms. A good $\frac{1}{12}$ in. oil immersion objective and suitable condenser are necessary for bacteriological work.

Refs. : Cunningham ; Lee (1937), *Microtomists' vade mecum*, London ; Martin and Johnston (1931), *Practical Microscopy*, London ; Bennett *et al.* (1941), *Phase Microscopy : Milk Testing*; Hughes and Cardew (1954), *LP*, 3, 10 (phase contrast).

MICROSCOPIC COUNT. This is the most direct way of counting bacteria in milk and has well-marked advantages and disadvantages.

Although not generally used in this country, except when a quick result is required, the direct count is recognised in America as a standard technique of equal standing with the colony count (*SMDP*). For this method a microscope with an oil immersion $\frac{1}{12}$ in. objective, slides, stains, and a capillary pipette which discharges 0·01 ml. of milk are required. The pipette should be calibrated by weighing the amount of milk discharged, which should be 0·0103 g. When using this technique, cleanliness of glassware is more important than sterilisation. After thorough shaking of the sample 0·01 ml. is blown out on to a clean glass slide and spread uniformly over an area of 1 sq. cm. with a clean stiff needle. This may be done either by using an etched area on the slide itself or by using a guide plate beneath the slide. After spreading, the milk film is dried in a warm place on a level surface and in a clean atmosphere. The drying should occupy from 5 to 10 min., after which the slides are dipped in xylol for 1 min., drained and dried. They are then immersed in 90 per cent. alcohol for 1 min. and then stained in the following solution : saturated alcoholic methylene blue 30 ml., distilled water 100 ml., for 1 min. A simpler procedure is, after drying, to immerse the slides in Newman's stain for 30 sec.

Methylene blue	1 g.
Glacial acetic acid	6 ml.
Tetrachlorethane	40 ml.
Ethyl alcohol 95 per cent.	54 ml.

This preparation removes the fat and stains the bacteria in one operation. If over-stained, the slides should be rinsed in water and decolorised in alcohol. When properly stained or adequately decolorised the background of the film should be a very faint blue.

The size of the microscopic field should be adjusted to a diameter of 0·206 or 0·146 mm., using a micrometer slide ruled in hundredths of a millimetre. The area of the field is then approximately $\frac{1}{3000}$ or $\frac{1}{6000}$ sq. cm., *i.e.* each field is equivalent to $\frac{1}{300000}$ or $\frac{1}{600000}$ ml. of the milk ; usually 30 fields are counted and the average number of bacteria per field multiplied by 300,000 or 600,000. This gives the estimated number of bacteria per ml. In the case of very clean and very dirty milks it is unnecessary to make actual counts ; thus if only an occasional bacterium is seen the milk may safely be described as " clean ", and if many bacteria are seen in every field the milk is " dirty ". The standard plate count usually averages about one-quarter of the total number of *individual* bacteria present as estimated by the direct microscopic count. This is because some organisms are dead, and clumps may contain many bacteria but form only one colony on a plate. By making *clump* counts instead of individual bacterium counts, the counts so obtained correspond fairly well with the agar plate count. *See* Bacteriological grading ; Mastitis ; Testing of milk supplies.

Refs.: Chalmers ; Wilson *et al.* ; *Milk Testing.*

MICROSCOPIC EXAMINATION. (i) **General.** The material should first be examined with the $\frac{2}{3}$ in. objective and reflected light. If a higher magnification is required the substance should be powdered (if this is permissible), placed on a slide and covered with a slip. It may then be examined both by reflected and transmitted light, in the latter case with the condenser suitably adjusted. The $\frac{1}{12}$ in. oil immersion objective should be used only by a trained worker ; a similar high magnification can be obtained with a $\frac{1}{6}$ in. dry objective and a high power eyepiece. Always rack *upwards* away from the object when focussing.

(ii) **Colonies of Micro-organisms.** Colonies may be examined with the $\frac{2}{3}$ in. objective without removing the lid of the Petri dish. If the latter is removed for further examination, a sub-culture should first be made.

The individual cells in a bacterial colony may be seen by using a high power ocular with a $\frac{1}{6}$ in. objective.

(iii) **Bacterial Cells.** A very small speck of the colony should be rubbed up with a little tapwater on a slide using a platinum loop. The final suspension should be only *just* turbid. Dry slowly over a bunsen flame or other source of warmth. Stain by (*a*) ordinary methylene blue, (*b*) Newman's stain (p. 236), or (*c*) Gram's stain (p. 235).

The first is adequate for ordinary work ; the second to be recommended when fat is present. Gram's stain gives more information in defining the cells as Gram positive or negative (p. 493) but the structure cannot be seen. *See* Bacteriological grading ; Microscopic count ; Platform testing ; Routine tests.

Refs.: Chalmers ; Cunningham ; Hammer ; Wilson *et al.*

MICROSOMES, MILK.

Refs.: Morton (1953), *N*, **171**, 734.

MILE. 1760 yd. or 1609·34 metres.

MILK. There is no legal definition of milk, but it is generally defined or described as the liquid obtained from the mammary gland of the healthy and normally fed cow.

In the 1949 Regulations (*see* Legal aspects) milk is defined as " cow's milk, but does not include cream,, or separated, skimmed, dried, condensed or evaporated milk, or buttermilk ". This definition is obviously an *ad hoc* one for the purpose of the regulations. The present legal position in England and Wales is discussed in Richmond (*q.v.*).

All attempts to define milk more accurately lead to difficulties but some authorities specify complete milking, not earlier than 15 days after calving, a minimum of 3 per cent. fat and 8·5 per cent. solids-not-fat, freshness, cleanness, etc. Scientifically there is no reason why milk should not be defined in terms of chemical constitution and ranges of concentration of the constituents. *See* Abnormal milk; Composition, factors affecting; Legal aspects; Nutritive value; Quality payment.

MILK-BORN DISEASES. *See* Diseases.

"MILK CHAMPAGNE." A popular name given to the effervescent alcoholic fermented milks such as kumiss (p. 568).

MILK FEVER. A physiological illness of freshly-calved cows due to lack of calcium.

Refs.: Miller; Hibbs (1950), *JDS*, **33**, 758 (review).

MILK MARKETING SCHEME (England and Wales). The Agricultural Marketing Act of 1931 enabled producers to set up Marketing Schemes to control effectively the marketing of their produce. The economic depression of the early thirties was world wide and the prices paid to primary producers were very low and supplies were in excess of effective demand. The position in this country was serious and the production of milk had become uneconomic, but not to the same extent as some of the other agricultural products. Milk, however, was the most important single farm product sold and amounted to about 30 per cent. of the total agricultural output.

Prior to the setting up of the Milk Marketing Scheme in 1933, negotiations in regard to milk prices and contracts were made through the Permanent Joint Milk Committee which consisted of the National Farmers' Union representing milk producers, and members representing the distributors and manufacturers. Negotiations under the Permanent Joint Milk Committee by 1932 had become completely unsatisfactory and chaotic. The Reorganisation Commission for Milk was set up in 1932 and the Commission reported in 1933 and recommended national organisation—a Milk Marketing Scheme in order to strengthen the collective marketing machinery of milk producers. The main principles and objects set out in this report (on p. 75) were:

(*a*) The strengthening of the position of the producers, by enabling them to negotiate as a solid body with one voice and with adequate information, and by ensuring that negotiated agreements are universally observed.

(*b*) The prevention of under-cutting of the liquid market, and the provision of satisfactory arrangements for the sale of milk for manufacture. This is necessary to establish a clear distinction between the two markets for milk—liquid consumption and manufacture—and to secure the return to producers of their fair share of the proceeds of all milk sold in the primary and more lucrative market.

(*c*) The improvement of the quality of our milk supplies.

(*d*) The stimulation of the demand for milk for liquid consumption.

(*e*) The recognition of the service rendered by producers who cater primarily for the liquid-milk market.

(*f*) The development of the manufacture of milk products.

(*g*) The co-ordination of the efforts of all concerned, producers, distributors, and manufacturers, to secure prosperity for the whole milk industry of the country, but with adequate safeguards for the interests of the consuming public.

The Commission recommended that the industry should be regulated by a Joint Milk Council, representative of producers, distributors, and three independent members. Producers did not accept this proposal and the National Farmers' Union promoted the Milk Marketing Scheme in 1933 as provided for under the Agricultural Marketing Act of 1931. The position of the milk market at that time was serious and rapid steps were taken to bring the Scheme into operation immediately. In September, 1933, a poll of milk producers was taken under the provisions of the 1931 Act and 96 per cent. of the producers voted in favour of the Scheme. The Milk Marketing Scheme came into operation on October 6, 1933, and the sale of milk off farms has been controlled since then by the provisions of the Scheme.

The Milk Marketing Board was set up to operate the Scheme which is a producers' organisation consisting of 15 producers' representatives; 12 are elected from the 11 regions and 3 special members are elected by national vote. In addition, there are 3 co-opted members who are elected after consultation with the Ministry of Agriculture, making 18 Board Members in all. The country is divided into 11 regions for administrative purposes and for each region there is an elected Committee consisting of country representatives and these Regional Committees act in an advisory and consultative capacity to the Board. In addition there are other consultative committees dealing with other aspects of milk marketing and production. Each year a general meeting of producers is held in London to consider the accounts and report of the Board for the financial year. The Board mentions the major problems of the year under review and outlines future policy.

The Board's powers under the Milk Scheme are wide and in 1933 the object of the Government and producers was to introduce orderly and efficient marketing together with remunerative prices for milk. Due regard was given to the consumers as the Board had certain responsibilities to the Consumers' Committee. The main powers granted to the Board were (*a*) prescribing prices to be paid for milk, (*b*) fixing prices to be paid to producers, (*c*) improving the quality of milk, (*d*) improving and expanding the markets for milk and (*e*) introducing more efficient methods of transporting and marketing. In addition the Board has various other powers such as to buy and sell milk, promote agricultural co-operation, education, and research.

When the Board commenced operations in 1933 it was faced with a gigantic problem of building up an efficient organisation in a very short time to deal with milk which was being sold by 100,000 producers and purchased by 20,000 first-hand buyers on a very unstable and unremunerative market. There were two methods of sale : (1) milk sold wholesale by producers to distributors by means of a tri-party annual contract, setting out the prices and conditions of sale and (2) milk sold retail by producers direct to consumers regulated by means of a licence issued by the Board setting out certain conditions of sale. At the present time about 90 per cent. is sold on wholesale contract and the remainder by producer retailers.

In effect the Scheme provided a large number of individual producers with their own Statutory Board for the collective marketing and regulation of their produce. The producers had to conform to certain regulations and discipline in order that the Board could function efficiently and effectively. Producers were paid a uniform price for their milk within certain limits, irrespective of the utilisation, either for liquid or manufacture ; the latter realised a low price. The monthly regional price variation did not exceed 1d. per gal. and at the present time the variation is ½d. per gal. The uniformity in price was achieved by the pooling of the monies received from distributors for the milk. The distributors and manufacturers paid differential prices according to the use made of the milk, *e.g.* in 1933-34 the price charged for milk used for human consumption was 14d. per gal. and the average price for milk for manufacture was 4·96d. per gal. By 1938-39 the liquid price had increased to 16·25d. per gal. and manufacture to 6·60d. The setting up of the Board enabled national schemes to be operated which were beneficial to all parties concerned, producer, distributor, and consumer.

The total sales of milk passing through the Scheme showed a steady increase from the outset, as the stable market and the monthly milk cheque were relatively attractive and more and more producers who had previously not sold milk entered the milk market. The number of wholesale contracts increased from 79,000 in 1933-34 to 108,000 in 1938-39 and by 1952-53 amounted to no less than 142,350.

The total volume of milk increased from 856 million gal. in 1933-34 to 1,119 million in 1938-39, and then to 1,243 million in 1946-47. In 1947 the Government introduced the Agricultural Expansion Programme which gave further incentive to milk production. Supplies in 1947 were still wholly inadequate to meet the liquid demand, and it was not until 1950 that restrictions on ordinary domestic consumption were finally removed by the Ministry of Food after a substantial increase in output had taken place. Between 1946-47 and 1952-53, sales increased from 1,243 million gal. to 1,601 million, an increase of 358 million or nearly 30 per cent. This marked increase in the milk supply was attributable to expansion in the cow population and especially the improvement in the yield per cow. All the regions showed increases in milk supplies, but the greatest increases came from the north, and the western regions, namely Far Western, Welsh, and Northern. There was, however, one exception, namely the Eastern Region, which also showed an appreciable increase. At the outbreak of the war the yield per cow commenced to decline due to the reduction of imported concentrates and by 1940-41 the average annual yield per cow had declined by about 15 per cent. and by 1946-47 the pre-war yield had not been regained. During the following years yields steadily improved by more efficient dairy herd management ; and by 1952-53 the average yield per cow had risen to 12½ per cent. above pre-war, even though purchased concentrates were still rationed. It is necessary to record that milk producers achieved remarkable results during the war in maintaining a high output when taking into account the feeding-stuffs difficulty, together with the marked change over to increased winter milk production.

TOTAL SALES (MILLION GALLONS)

	1938-39	1946-47	1952-53
Winter . .	487	581	751
Summer . .	632	662	850
Year . .	1,119	1,243	1,601

The rapid increase in sales through the Scheme between 1933 and 1939 resulted in appreciable quantities of milk for manufacture and considerable effort was necessary by the Board to exploit the manufacturing market to the full. Home-produced, manufactured products were in direct competition with imported products, although there was a small subsidy on manufactured milk, as the Government guaranteed a minimum price of 5d. per gal. However, some quota regulations were introduced, fixing the maximum quantities which could be imported from foreign countries. In addition the Board expanded the market for the higher priced products such as milk for chocolate, condensed milk, and fresh cream. There was an appreciable improvement in the quality of home-produced products as the price policy of milk for manufacture was stabilised, which gave security to manufacturers. The quantity of milk available for manufacture from 1939-40 until 1948-49 was low, due to the large increase in liquid consumption as compared with pre-war. In 1949-50, however, the quantity of milk manufactured increased by about 100 million over the average of the 5 previous years, but was still only about ⅔ of the pre-war figure. The following 2 years showed some recession in manufacture due to a lower level of total output together with a slightly higher liquid demand. In 1952-53 there was a further increase in the volume manufactured as output was the highest recorded, while liquid consumption declined slightly.

From the early days of the Scheme the Board found it necessary to set up manufacturing creameries in the outlying areas to deal with surplus milk where there was a large number of new milk producers. The total number of Board's creameries in 1953 was 12, including a new processing and bottling creamery in Durham. Since 1940, owing to the high demand for liquid milk, the creameries had to change their function from manufacture to dispatching liquid milk, except for a short time at some creameries in the flush period of production. These creameries have formed a very useful service in dealing with milk in remote areas which would have otherwise been difficult to market.

From the outset the Board have investigated every aspect in regard to improving the quality of milk and increasing consumption and at the same time endeavoured to give the consumer the best product possible at a fair price. In order to improve the quality of milk the Accredited Scheme was introduced in May, 1935, and producers received a premium of 1d. per gal. for milk of this standard. This scheme was financed by producers' money coming from the pool funds. A steady expansion of accredited milk took place and by 1938-39 the annual production amounted to 416 million gal. or 37 per cent. of total supplies. No additional charge was made to the distributor or consumer for this higher quality milk. In order to eradicate tuberculosis from the dairy herds the Government introduced the Attested Herd Scheme in 1935 and a premium of 1d. per gal. or a capitation bonus was paid to producers having attested herds.

Under the Milk Industry Act, 1938, the whole field of quality milk was reviewed by the Government and the Board. The object was to stimulate and increase the production of quality milk and in consequence the premiums for all categories of quality milk were increased, *i.e.* Tuberculin Tested, Accredited and for milk produced from attested herds, the Government and the Board contributing to the premiums paid.

PREMIUMS PAID TO WHOLESALE PRODUCERS FOR QUALITY MILK

Grade	1938-39 *Government*	 *Board*	 *Total*	1952-53
		(pence per gal.)		
Accredited	¾	½	1¼	1¼
Tuberculin Tested	1¼	1	2¼	2
Accredited and Attested . . .	2¼	1	3¼	3¼
Tuberculin Tested and Attested . .	2¼	1	3¼	4
Attested	1½	½	2	2

Further stimulus was given to the production of Tuberculin Tested milk in 1943 when the premium was increased to 4d. per gal. A substantial expansion in the output of Tuberculin Tested milk has taken place, and now amounts to more than half of the milk supply, compared with 6 per cent. pre-war. New regulations come into operation on 30th September, 1954, whereby no new Tuberculin Tested licence will be issued unless the herd is attested, while the Accredited licence will be terminated. In 1950 the Attested Herds Scheme was amended which provided for a bonus of 2d. per gallon for four years and 1d. per gallon for a further two years, or capitation payments. The premium for Tuberculin Tested milk was amended to 2d. per gallon. In view of the rapid progress made in attestation after the end of the war until 1950, it was decided that the complete eradication of bovine tuberculosis from the dairy herds of this country should be the aim, and the Minister of Agriculture should specify eradication areas. This has been done for some counties in Wales and in the north. Already some counties have been scheduled as Attested areas in Wales. The number of quality herds in 1938-39, 1946-47, and 1952-53 was :—

	Accredited	*Tuberculin Tested*	*Attested*
1938-39 . . .	25,300	3,900	6,000
1946-47 . . .	22,100	13,200	17,100
1952-53 . . .	14,000	45,500	66,500

In order to increase the consumption of liquid milk which was the most remunerative outlet, various schemes were introduced. Prior to 1934 the National

Milk Publicity Council had endeavoured to popularise school milk on a voluntary basis. However, the Board, in conjunction with the Government and distributors introduced the School Milk Scheme, enabling children to obtain milk at a reduced price of ½d. per ⅓ pint or 1s. per gal. which was less than half the retail price. The expense of this scheme was borne about equally by producers, Government, and distributors. The distributors worked on a reduced margin of 6d. per gal. as compared with an average margin of 11d. The quantity of milk sold in schools per annum increased from about 8 million gal. in 1933-34 to 22 million gal. in 1935-36. There have been certain changes in regard to the Milk in Schools Scheme. Distributors now receive the same margin for distribution as ordinary milk and from August, 1946, the children obtain ⅓ pint per day free of charge. The annual consumption in schools now is around 44 million gal. at ⅓ pint per day. The object of this scheme is to improve the nutrition of the children and establish the milk-drinking habit when they become adults.

In 1936 the Board, in co-operation with the Government and the distributors, carried out experiments in the " depressed areas " whereby cheap milk was made available at the rate of 1 pint per day for children under 5 years of age and nursing and expectant mothers, where the family incomes were low. The charge was 2d. per pint or free, according to circumstances. These Schemes were carried on until 1939 and were successful from the outset as they demonstrated the necessity of increasing the consumption of milk in the low income groups. Further expansion took place in 1940 : the Ministry of Food launched the National Milk Scheme for all children and nursing and expectant mothers, based on very similar lines as the experimental Schemes. The price of this milk is now 1½d. per pint or free when the family income is low. Both these Schemes form part of the Government's social policy and are regulated under the Welfare Foods Order.

The other aspects of increasing liquid consumption were developed by widespread publicity before the war and the introduction of industrial milk and the promotion of milk bars. Some 2 million industrial and office workers were taking milk during working hours and this was quite an achievement as there was no reduction in the price. Very satisfactory progress was made in setting up of milk bars and by 1939 over 1000 bars were operating throughout the country.

There was a steady and gradual increase in the consumption of liquid milk from 1933-34 to 1939-40. After 1940 there was a rapid increase in consumption, due to the expansion of the Milk in Schools and the National Milk Schemes, together with the increased demand from the industrial areas where pre-war low incomes prevailed and, of course, the shortage of other foods. The shift in consumption has necessitated the introduction of milk allowances even in spite of an increase of 50 per cent. in the volume of milk sold for liquid consumption as compared with 1938-39. By 1950 it was possible for the Ministry of Food to remove restrictions on milk for domestic consumption although the autumn trough in production which occurs in August and September necessitated transferring milk to England and Wales from Scotland and Northern Ireland. The average consumption per head per day is now equal to 0·72 pint as compared with 0·43 pint pre-war, although there has been a tendency for consumption to decline from the peak in 1951, probably due to the greater availability of other foodstuffs, and also the higher retail price now charged for milk. There are, however, indications that consumption had ceased to decline by the end of 1953.

From 1940 the Ministry of Food took over certain responsibilities of the Board, but the Board still operated and acted as agent of the Ministry in some aspects of control. The producers' prices were guaranteed and the whole price structure of distributive margins changed. The Ministry of Food was responsible for fixing retail prices, distributors' prices and margins, while the Ministry of Agriculture fix producers' prices as laid down under the Agriculture Act, 1947. It can be said that the Ministry of Food controlled the direction of milk after it was delivered to the distributors while the Board still retained full control of production and the producers. One of the main changes which took place in 1942 was for the total milk supply to be sold to the Ministry instead of to individual distributors. This was done in order to facilitate the direction of supplies to the areas where milk was in short supply to meet liquid requirements. On this basis, producers sold their milk to the Board, and the Board, in turn, sold to the Ministry. At the time of this contract change, the responsibility of transporting the milk from the farm to the first destination became the Board's ; it was previously the producers'. Here again, this change was necessary in order to redirect supplies to the right consuming centres.

Sales of Milk for Liquid Consumption (Million Gal.)

Oct.-Sept.		*Oct.-Sept.*		*Oct.-Sept.*	
1933-34	643	1940-41	926	1947-48	1184
1934-35	665	1941-42	971	1948-49	1312
1935-36	664	1942-43	1017	1949-50	1347
1936-37	681	1943-44	1048	1950-51	1375
1937-38	752	1944-45	1071	1951-52	1363
1938-39	767	1945-46	1132	1952-53	1341
1939-40	789	1946-47	1145		

In November, 1953, a White Paper was issued on the Decontrol of Food and Marketing of Agricultural Produce. The Government stated that controls were to be ended as soon as practicable but would firmly adhere to the principles of the Agriculture Act, 1947, and fully accept their obligations to make alternative arrangements to secure a stable and efficient agricultural industry. The Government decided that full marketing powers would be restored to the Milk Marketing Boards in Great Britain in 1954 for all milk, both liquid and milk sold for manufacturing purposes. Such powers were restored to the Boards on the 1st April, 1954, subject to necessary safeguards for the Exchequer, the consumer and other interests. The continuance of an element of consumer subsidy will involve approval by the Government of the level of prices and distributive margins. The Welfare and School Milk Schemes will continue.

From the 1st April, 1954, the Board for England and Wales took over the responsibility as the marketing authority for the sale of all milk and arranged contract conditions with the distributors to cover the sale of milk for liquid consumption and manufacturing purposes. A Joint Committee composed of members of the Board and the Central Milk Distributive Committee negotiates all milk marketing matters. The Board are fully aware of the problems confronting the dairy industry after fourteen years of control and with the co-operation of the distributors will carry our their marketing responsibilities efficiently.

A new method of price guarantee has been introduced from the 1st April, 1954. The Government now guarantee a price per gallon at the February Review which is related to a Standard Quantity of milk. For 1954-55 this equals the estimated total sales of milk off farms for the year ended March, 1953-54 of 1,651 million gallons. The Government are now limiting for the first time, the extent of their liability, and if the sales of milk exceed the standard quantity the excess will only qualify for the manufacturing milk price which will reduce the effective level of the guaranteed price. The price guarantee is to the Board and is not an individual producer guarantee like some of the other livestock commodities. The guaranteed price is related to a formula which gives an incentive to the Board to obtain the best possible price for milk used for manufacture and also to expand the liquid market.

Producers' prices have increased appreciably, but this can be accounted for by the very large increase which has taken place in agricultural wages. The ordinary adult male worker has had an increase from 34s. per week in 1938-39 to 120s. in 1953, together with a reduction in the number of hours worked per week. In addition, the shortage of imported feeding-stuffs has made the producer use much more home-grown bulky foods, which are relatively expensive to produce. Compared with pre-war, purchased concentrates now cost the milk producer more than 4 times as much. The two major items in the cost of milk production are labour and feeding-stuffs, accounting for no less than 80 per cent. of the total cost.

The Board have been conscious of the need since 1940 to increase production and efficiency to meet the national requirements in every way. During the war years they assisted the Ministry of Agriculture in its campaign for increased milk production. In consultation with the Ministry, the National Milk Records Scheme was set up in 1943, in order to increase the yield of milk per cow and improve the breeding and management of the dairy cows. Rapid progress has been made in the number of herds recorded and when the Board took over in 1943 there were some 4,100 recorded herds and now there are 25,300. This Scheme is financed by the Ministry, the Board, and producers, and to a large extent the policy of milk recording is directed by the members under the National Milk Records Advisory Committee.

In addition, a Bureau of Milk Records has been set up in order that the performance of the recorded cows is available to assist in the breeding policy and particularly in regard to pedigree dairy animals. This information will prove invaluable for improving and grading up the dairy herds which will ultimately lead to increased output and efficiency.

It has been recognised that artificial insemination has passed its experimental stage, and the Board in 1944 commenced to operate Artificial Insemination Centres. In 1953, 81 centres and sub-centres were operating giving a service to nearly 110,000 producers which makes available the best dairy bulls to a very large number of producers. It must be remembered that a very large proportion of the dairy farmers have small herds, in fact 66 per cent. of them have 15 cows or less, and in herds of this size it is highly uneconomic to maintain a first class bull. This scheme is now firmly established and it should bring considerable improvement in regard to the breeding policy of the dairy farmer within a relatively short period as nearly 1,000,000 cows were inseminated in 1952-53.

Another aspect in which the Board have been interested is the problem of grass drying, in order to make better use of the home-grown foods available and to make up for the lack of imported protein. In 1947 an experimental drying plant was operated in Gloucestershire and satisfactory results were obtained. In 1948, after consultation with the Ministry of Agriculture, additional plants were erected and now there are 11 in operation. These plants have rendered invaluable service to the producers co-operating, although the need in future may lessen as greater and cheaper supplies of imported concentrated feeding-stuffs become available.

Both the producers and the Board are enthusiastic in regard to increasing efficiency and output and realise the necessity to increase the output of high quality milk at an economic level. The costs and economics of milk production have been under review since 1934 and this information has been collected by the Advisory Agricultural Economists attached to the various Universities and Agricultural Colleges. This scheme was financed solely by the Board from 1934 to 1946 and since 1946 the expense is shared equally with the Ministry of Agriculture. The data collected have been invaluable.

The National Milk Testing and Advisory Scheme introduced in 1942 and carried out by the Ministry of Agriculture for testing and keeping quality of producers' milk was terminated in 1949. The responsibility for testing and controlling the marketable standard of milk was passed to the Joint Milk Quality Control Committee which consists of representatives of producers and distributors.

Some statistics are given in the following tables and figures which are of interest to illustrate the growth and expansion of the Scheme.

TABLE MMS I

Total Sales in England and Wales (Million Gal.)

Oct.–Sept.	*Liquid*		*Manufacture*		*Total*
	Gal.	*%*	*Gal.*	*%*	*Gal.*
1933-34 . . .	643	75·1	213	24·9	856
1934-35 . . .	665	67·8	316	32·2	981
1935-36 . . .	664	64·9	360	35·1	1024
1936-37 . . .	681	68·8	309	31·2	990
1937-38 . . .	752	70·7	311	29·3	1063
1938-39 . . .	767	68·5	352	31·5	1119
1939-40 . . .	789	73·7	282	26·3	1071
1940-41 . .	926	88·6	119	11·4	1045
1941-42 . . .	971	90·0	108	10·0	1079
1942-43 . . .	1017	88·8	128	11·2	1145
1943-44 . . .	1048	88·8	132	11·2	1180
1944-45 . . .	1071	89·0	133	11·0	1204
1945-46 . . .	1132	89·9	127	10·1	1259
1946-47 . . .	1145	92·1	98	7·9	1243
1947-48 . . .	1184	89·6	137	10·4	1321
1948-49 . . .	1312	89·9	147	10·1	1459
1949-50 . . .	1347	84·9	239	15·1	1586
1950-51 . . .	1375	90·2	150	9·8	1525
1951-52 . . .	1363	89·1	167	10·9	1530
1952-53 . . .	1341	83·8	260	16·2	1601

TABLE MMS II

Regional Sales (Million Gal.)

Region	1933-34	1938-39	1946-47	1950-51	1952-53
1. Northern . .	51·85	78·74	109·85	137·57	146·60
2. North Western .	247·24	309 25	307·63	374·37	377•72
3. Eastern . .	41·42	62·37	73·73	93·60	91·75
4. East Midland .	65·40	82·74	85·11	100·83	98·83
5. West Midland .	73·26	96·42	113·55	141·76	154·03
6. North Wales .	17·97	31·45	52·08	66·84	71·89
7. South Wales .	28·88	49·89	70·91	91·24	104·71
8. Southern . .	66·15	80·93	80·83	97·81	100·01
9. Mid-Western .	137·66	162·76	163·92	193·63	212·48
10. Far Western .	29·80	54·63	79·46	102·14	118·32
11. South Eastern .	95·99	109·52	105·63	125·19	124·68
All regions .	855·62	1,118·70	1,242·70	1,524·98	1,601·02

TABLE MMS III

Utilisation of Manufactured Milk (Million Gal.)

Oct.–Sept.	Butter	Cheese		Condensed milk	Milk powder	Fresh cream	Tinned and bottled cream	Other products	Total
		Factory	Farm						
1933-34 . . .	41·5	62·1	18·8	40·2	8·5	32·8	5·5	3·4	212·8
1934-35 . . .	83·7	92·6	14·0	57·7	13·0	41·3	7·7	5·7	315·7
1935-36 . . .	120·7	89·8	17·7	63·6	13·8	39·3	8·0	7·2	360·1
1936-37 . . .	101·0	59·0	19·6	62·6	8·5	43·0	10·3	4·7	308·8
1937-38 . . .	77·1	53·6	23·8	80·5	13·6	46·6	10·6	5·1	310·9
1938-39 . . .	101·3	67·3	20·8	81·0	17·3	48·9	11·0	4·3	351·9
1939-40 . . .	71·2	56·6	15·5	82·6	15·2	27·1	7·2	6·6	282·0
1940-41 . . .	19·0	46·4	9·0	27·4	12·2			4·6	118·6
1941-42 . . .	28·0	27·4	5·8	31·9	12·8			1·8	107·7
1942-43 . . .	23·0	35·8	4·1	32·7	30·9			1·3	127·8
1943-44 . . .	31·7	29·4	3·4	38·5	28·1			1·3	132·4
1944-45 . . .	21·9	37·3	3·1	30·5	38·1			2·2	133·1
1945-46 . . .	27·8	41·5	2·8	21·1	32·7			1·3	127·2
1946-47 . . .	16·8	30·7	2·3	15·8	31·2			1·1	97·9
1947-48 . . .	17·3	38·9	2·6	19·8	56·6			1·8	137·0
1948-49 . . .	28·6	60·5	2·7	28·1	25·6			1·7	147·2
1949-50 . . .	47·2	102·1	4·0	48·4	33·4			3·5	238·6
1950-51 . . .	7·5	79·4	4·4	26·1	24·4	6·0 *		2·2	150·0
1951-52 . . .	13·4	89·1	5·0	32·6	24·4			2·2	166·7
1952-53 . . .	29·6	137·2	5·8	46·5	24·5	5·9 †	7·3 †	3·3	260·1

* Estimated. † From 1st April, 1953.

TABLE MMS IV

School and National Milk Schemes

	Million gal.	
	School milk	*National milk*
1933-34 (voluntary basis) . .	8	—
1934-35	23	—
1935-36	22	—
1936-37	23	—
1937-38	26	—
1938-39	26	—
1939-40	22	15
1940-41	27	104
1941-42	38	114
1942-43	42	133
1943-44	43	146
1944-45	41	150
1945-46	43	157
1946-47	39	161
1947-48	42	158
1948-49	43	164
1949-50	42	160
1950-51	42	161
1951-52	44	155
1952-53	44	148

TABLE MMS V

Prices Paid to Wholesale Producers†

(*Weighted average prices*)

Oct.-Sept.	*Pence per gal.*		
	Winter	*Summer*	*Year*
1933-34	13·54	10·46	11·83
1934-35	13·82	10·48	11·99
1935-36	13·32	9·96	11·48
1936-37	13·74	10·53	11·99
1937-38	14·83	11·41	12·92
1938-39	14·81	11·55	12·95
1939-40	16·14	14·73	15·36
1940-41	22·14	16·48	18·98
1941-42	27·09	17·33	21·42
1942-43 * . . .	29·21	17·29	22·31
1943-44 * . . .	29·67	17·74	23·01
1944-45 * . . .	29·81	18·33	23·37
1945-46 * . . .	30·58	19·65	24·53
1946-47 * . . .	32·30	20·98	26·25
1947-48 *	35·49	23·18	28·59
1948-49 * . . .	35·12	24·76	29·64
1949-50 * . . .	37·93	25·83	31·54
1950-51 *	38·79	27·14	32·80
1951-52 *	40·90	28·94	34·66
1952-53 *	42·17	29·31	35·31

* Excludes production bonus.

† Excluding quality premiums.

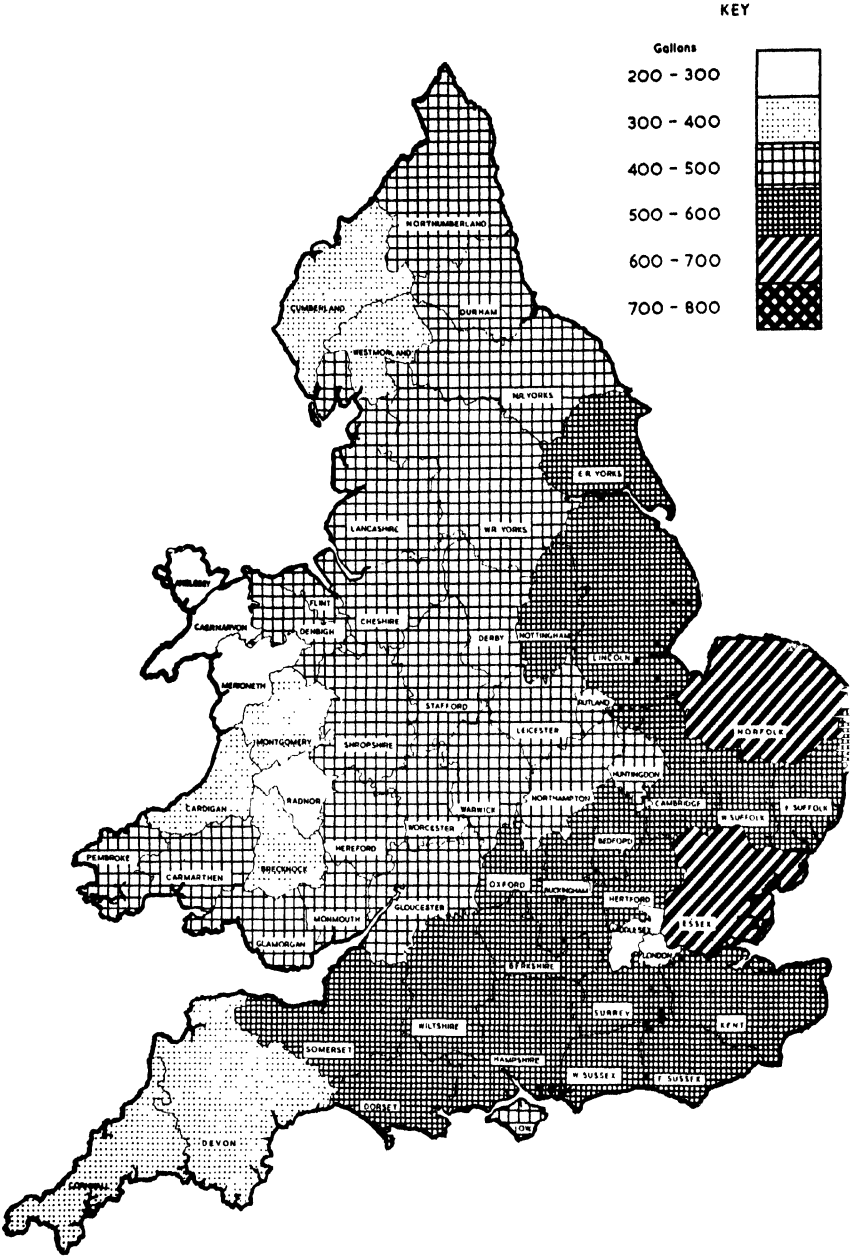
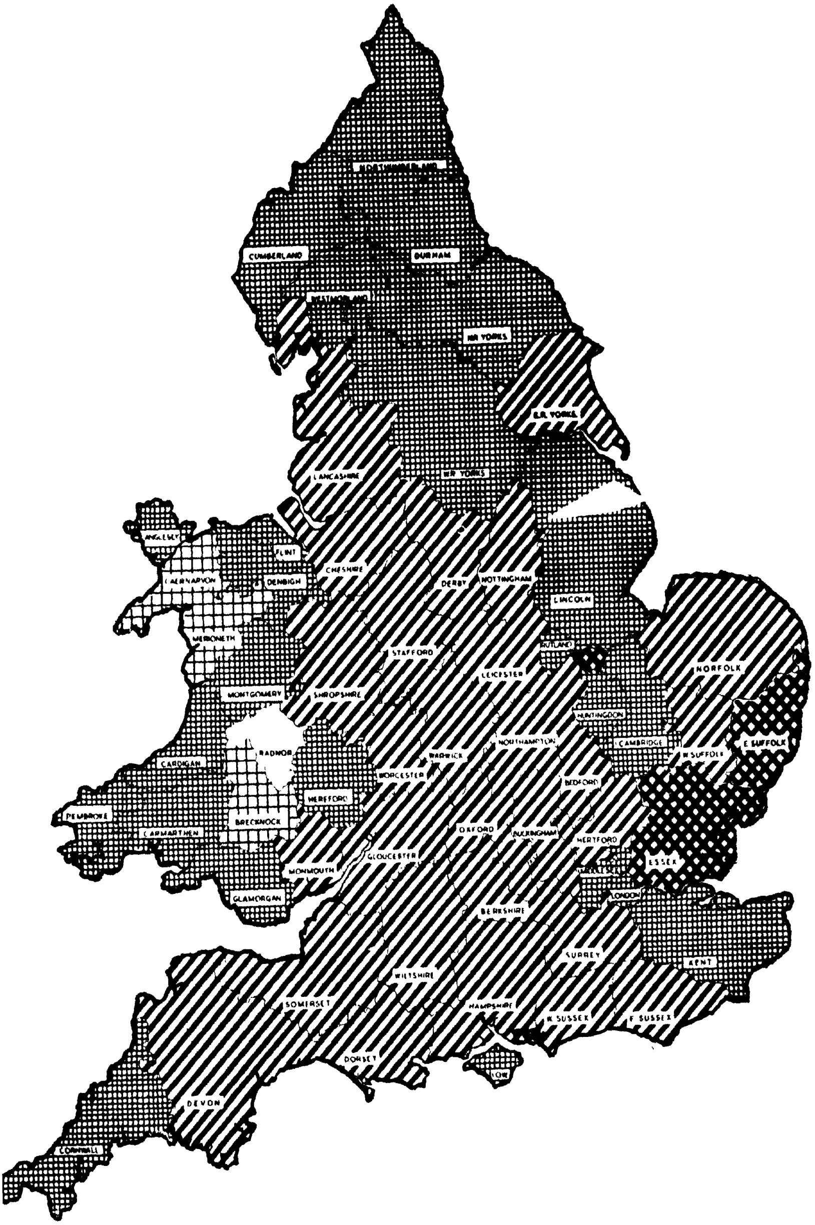


FIG. MMS 1.—*Sales of Milk off Farms in England and Wales* 1942-43. *Gallons per Cow.*



[*Maps by courtesy of the Milk Marketing Board.*

FIG. MMS 2.—*Sales of Milk off Farms in England and Wales,* 1952-53. *Gallons per Cow.*

TABLE MMS VI

ESTIMATED VALU OF ALL MILK SOLD THROUGH THE BOARD †

October-September	£ *Millions*	*October-September*	£ *Millions*
1933-34	42·2	1943-44 *	113·2
1934-35	49·0	1944-45 *	117·3
1935-36	49·0	1945-46 *	128·7
1936-37	49·5	1946-47 *	136·0
1937-38	57·2	1947-48 *	157·4
1938-39	60·4	1948-49 *	180·2
1939-40	68·5	1949-50 *	208·4
1940-41	82·6	1950-51 *	208·4
1941-42	96·3	1951-52 *	220·9
1942-43	106·4	1952-53 *	235·5

* Excludes production bonus.
† Excluding quality premiums.

TABLE MMS VII

COMPARISON OF PRODUCERS SELLING MILK, AS SHOWN BY BOARD'S RECORDS OF CONTRACTS AND LICENCES

Wholesale suppliers

Year	*Number*	*Year*	*Number*
1934	78,895	1944	131,368
1935	86,305	1945	132,104
1936	90,350	1946	134,710
1937	92,935	1947	136,444
1938	101,276	1948	140,953
1939	108,018	1949	143,563
1940	112,861	1950	145,991
1941	119,971	1951	144,834
1942	127,055	1952	143,247
1943	131,326	1953	142,344

Producer-retailers

Year	*Number*	*Year*	*Number*
1934	46,801	1944	54,913
1935	65,744	1945	52,450
1936	66,279	1946	49,216
1937	64,089	1947	46,020
1938	63,305	1948	43,420
1939	61,881	1949	40,703
1940	61,035	1950	37,814
1941	64,369	1951	35,339
1942	60,326	1952	33,224
1943	57,387	1953	30,607

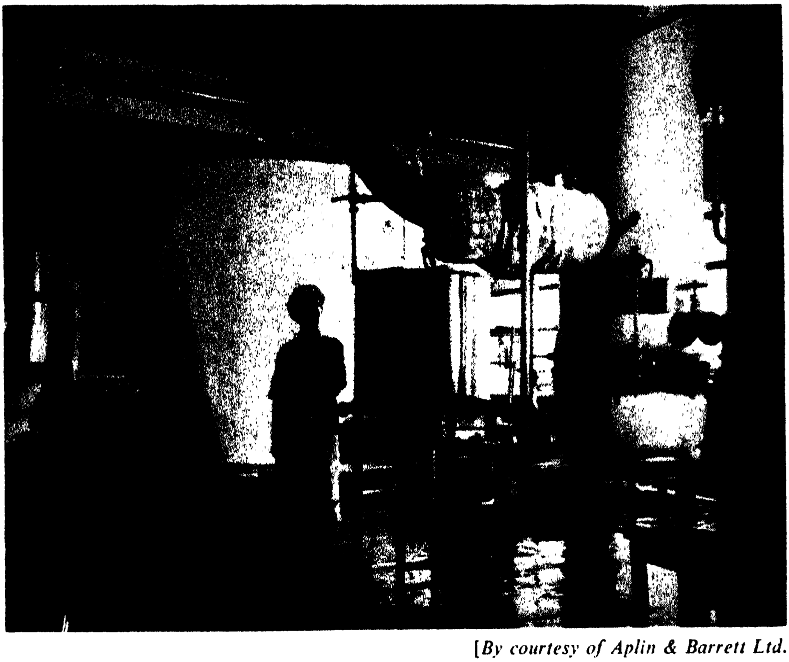
See Costings ; Legal aspects ; Utilisation.

Refs.: Milk Production, Reports Nos. 1, 2, 3 and 4, M.M.B. ; Min. Agric. (1936). *Report of the Reorganisation Commission*, H.M.S.O.

MILK POWDER. Milk powder is produced by the removal of the water from milk by heat or other means to produce a solid containing 3 per cent. or less moisture. Whole milk, milk from which part of the cream has been removed or skim milk may be used for this purpose, and the processes are also applied to by-products such as buttermilk and whey.

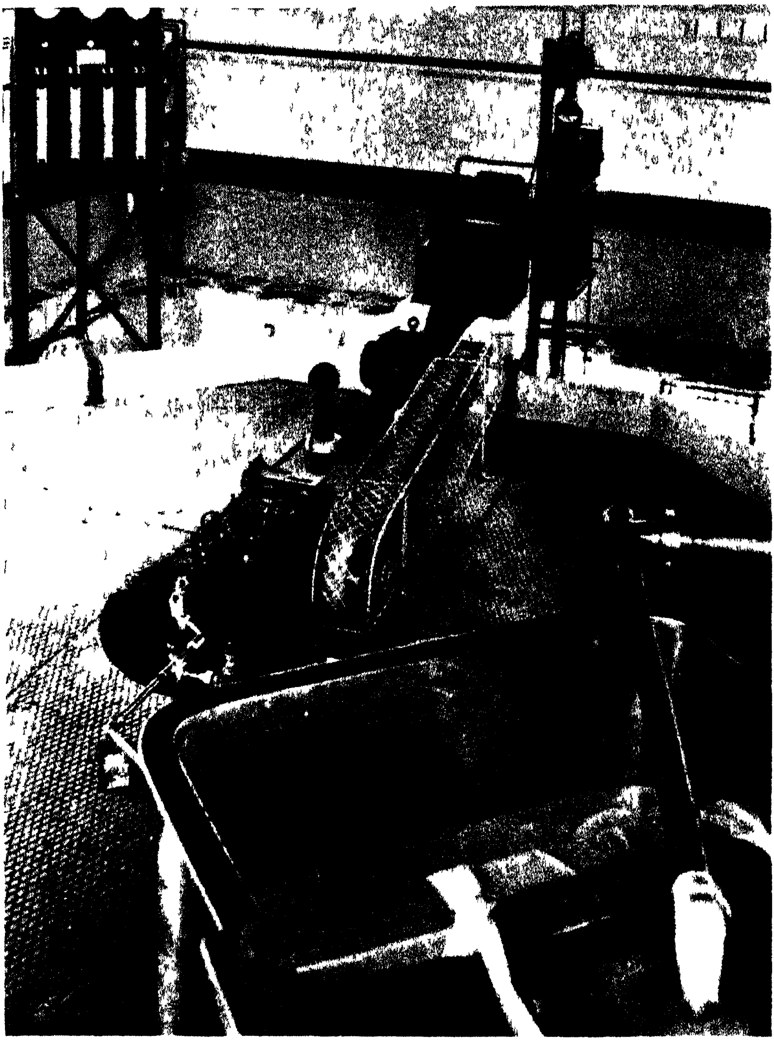
[*By courtesy of the Milk Marketing Board.*

FIG. MP 1.—*Milk Powder Roller Drying Plant.*



[*By courtesy of Aplin & Barrett Ltd.*

FIG. MP 2.—*Spray Drying Plant, Continuous Evaporator Control.*



[*By courtesy of Aplin & Barrett Ltd*

FIG. MP 3.—*Top of Kestner Drying Chamber showing Evaporated Milk Passing to Atomiser (centre) with Atomiser Revolution Indicator (near electric motor) and Instrument Board in Left Corner.*

The sale of milk powder is controlled by the Public Health (Dried Milk) Regulations, 1923 and 1927 which recognise four types of powder and stipulate that:

	% butterfat
Dried Fullcream milk shall contain not less than	26
Dried ¾-cream milk shall contain not less than	20
Dried ½-cream milk shall contain not less than	14
Dried ¼-cream milk shall contain not less than	8

These Regulations apply to dried milk to which no other substance has been added and to dried milk contained in any powder or solid of which not less than 70 per cent. consists of dried milk contained in packages of not less than 10 lb. gross weight. The packages must be labelled in the prescribed manner and the equivalent of fullcream, ¾-cream, ½-cream or ¼-cream or skim milk in the container declared, using the following standards:

	Butterfat	*Milk solids (Incl. fat)*
Fullcream milk	3·6	12·4
¾-cream milk	2·7	11·6
½-cream milk . .	1·8	10·8
¼-cream milk	0·9	9·9

Skim milk is defined as containing not less than 9 per cent. of milk solids other than butter fat and any dried milk containing less than 8 per cent. butterfat must be labelled as dried skim milk.

For the purpose of calculating the equivalent of a package of dried milk after an analysis has been made, the following table given by Elsdon and Walker[1] in Richmond's *Dairy Chemistry* is useful. It gives the grams of butterfat and milk solids including fat contained in 1 pint of standard milks.

	Fullcream	*¾-cream*	*½-cream*	*¼-cream*	*Skim*
Total solids (g.) . .	72·69	68·08	63·37	58·16	52·91
Fat	21·11	15·84	10·55	5·27	—

Except for freeze-drying which has not yet become a commercial proposition but which according to Hunziker[2] shows great promise of doing so in the form of the latest American developments, milk powder is made by processes employing heat as the means of evaporating the water from the milk. Two processes are established commercially and are the Roller, Film or Drum, Process and the Spray Process.

Roller Process. In this process, milk is dried on the surface of a horizontal steel cylinder which is heated internally by means of steam (Figs. MP 1 and 4). The milk is spread in a thin film on the roller by suitable means and this film dries on the hot surface and after about ¾ of a rev. of the roller is removed by means of a scraper knife. This type of drying plant has the advantages of comparatively low initial cost, small space occupied and of being simple and economic in operation. Driers are made with either one or two rollers which vary in size from 3 to 12 ft. in length and 24 to 48 in. in diameter. The working-surface temperature of the drying rollers is about 300° F. and the speed about 15 r.p.m. giving a contact time of 3 sec.

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[1] Davis and Macdonald (1953), *Richmond's Dairy Chemistry*, C. Griffin & Co., Ltd., London.

[2] Hunziker (1946), *Condensed Milk and Powder*, Published by the author, La Grange, Illinois.

In machines using a single drying roller, the milk is fed on to the roller either by means of a spray or from a trough into which either the drying roller or an intermediate transfer roller dips. This type of machine will give very satisfactory results with milk precondensed to a concentration of 3 : 1 to 5 : 1. The commonest type of roller drier in use employs two drying rollers. The rollers which are in the same horizontal plane, are set parallel to one another so that when at working temperature, the gap between the rollers is of the order of 0·03 in. The rollers turn in opposite directions; viewed end-on the left hand roller rotates clockwise and the right hand roller anti-clockwise. The milk is fed into the trough formed by the rollers and may be slightly precondensed, 17 per cent. total solids being the limit to which this can be taken. Single and double roller machines in which the drying takes place in a vacuum chamber are made and produce high quality powder. They are more expensive to instal and run and the milk feed is precondensed to a concentration of 4 : 1.

The quality and quantity of the output of roller drying machines are influenced by a number of factors :

(1) The alignment of the rollers must be very accurate.

(2) Air venting and the removal of condensate must be efficient.

(3) The knife and the roller surface must be maintained in good condition. Knives must be reground as often as is necessary, 100 hr. is probably the average time of satisfactory working between grindings, and they must be carefully set on the machine so that no part of the film of dried milk is carried round the roller for a second time. The rollers will require re-surfacing after 2000 to 3000 hr. working time.

(4) The speed of rotation and working temperature of the rollers are very important. In roller drying some denaturing of the protein takes place with a detrimental effect on the reconstitution of the powder. The critical stage is that of high solids just before complete drying and the time-temperature ratio is critical. Better results are obtained by quick drying of a thin film of milk.

(5) Homogenisation of the milk prevents some breakdown of the fat emulsion which causes the fat to separate as oily drops on reconstitution and also results in some unevenness of the distribution of fat in the powder. Clarification of the milk before drying tends to improve the keeping quality of the powder.

(6) Preheating the milk before feeding on to the rollers slightly increases output and keeping quality but temperatures above 160° F. are detrimental to the reconstitution of the powder.

(7) The quality of the milk, especially its titratable acidity, is reflected in the quality of the powder produced.

After drying, roller powder is cooled to harden the butterfat and then sifted or ground. This process influences the size of the particles which are solid and irregular in shape.

Whey from cheese or acid casein manufacture can be successfully roller-dried after neutralisation with calcium hydroxide.[3]

Spray Process. In this process the milk in the form of a fine mist is dried by means of hot air in a suitably designed chamber. The spray gives a very large superficial area for a given quantity of milk and evaporation is extremely rapid. The absorbed heat is so rapidly utilised that the temperature of the solids does not rise to that of the surroundings until drying is practically complete and the process does not in general affect colloidal structure. Spray powder has a much greater bulk density than roller powder and the spherical form of the particles tends to prevent caking. Rapid and even mixing of the milk spray and hot air are essential for the production of an even particle size which is determined by the concentration of the milk when sprayed and the type of spraying mechanism employed.

[3] Waite (1941), *J. Dairy Res.*, **12**, 71

Three types of spraying mechanism are used: (i) centrifugal disc; (ii) high-pressure milk jet; (iii) by means of compressed air jets either concentric with or at right angles to a low-pressure milk jet.

It has been shown that the radius of the drop decreases up to a relative air speed of about 400 ft. per sec. after which no further reduction in size is effected. The centrifugal method consists of feeding the milk on to a saucer shaped disc rotating at speeds up to 16,000 r.p.m. depending on the diameter of the disc. The saucer shape gives a greater adhesion of the liquid and reduces slip which affects the degree and uniformity of atomisation. The disc should be situated in a cool zone of the drying chamber to prevent drying on the edge of the disc and a resulting loss of efficiency. The method has the advantages of easy cleaning and the absence of high pressures and small apertures which may become blocked. The high-pressure jets used on some types of plant work at pressures up to 2000 lb. per sq. in. They may become blocked by particles or incrustation of product and the size of the jet tends to be increased by erosion. There may be some variation of particle size between the outer edge and the inside of the cone of spray and this is least at high pressures.

The rate of settlement of the powder particles is affected by their size and the direction and velocity of the air flow. In earlier designs of drying chambers, by using a large chamber, low air temperatures (130° to 140° C.) and air speeds, most of the powder was deposited on the floor of the chamber and either continuously removed by mechanical means or allowed to remain until the end of the batch. Later types of drying chamber are of smaller size and give a high output by a short exposure of the milk spray to relatively high temperatures (150° to 170° C.). A strong downward air current carries the powder to the bottom of the chamber for continuous removal and the finer particles carried out of the chamber are recovered by means of cloth filters or cyclone separators. In one type of spray drier, the outgoing air from the drying chamber passes into a second chamber when a spray of milk dissolves out the entrained powder and the warm air produces a degree of concentration of the milk.

Precondensing the milk before spraying effects a large thermal economy and reduces the entrapped air within the particle, thus resulting in increased bulk density, greater ease of reconstitution, and improved keeping quality. Preheating the milk before drying destroys enzymes and bacteria and has a great effect on keeping quality. After preheating the milk is precondensed to 30 to 40 per cent. total solids in a vacuum evaporator.

Spray powder consists of slightly oval particles 5 to 150 microns in size and containing trapped air.

A spray powder plant utilising a climbing film evaporator is illustrated in Figs. MP 2 and 3.

General properties.

The method of drying has a fundamental influence upon the properties of milk powder. Roller dried milk consists of comparatively solid masses, irregular in shape and size, with little air enclosed inside the particles. The severe heat treatment to which the milk is exposed has bacteriological advantages, and the powder should contain only a few hundred organisms per gram, provided it is protected from contamination during grinding and packing. On the other hand, severe denaturation of the protein occurs and the powder is only soluble again in water to the extent of about 80-85 per cent. The normal fat globule structure is also destroyed and much of the fat is found on the surface of the powder particles; when reconstituted in water it rises to the surface as an oily layer. The general appearance of the reconstituted product is not, therefore, particularly attractive, whilst the flavour is definitely cooked. Moreover, very small variations in the temperature or speed of rotation of the rollers may result in the presence of burnt particles. These features do not seem to be of much importance in infant feeding, but they preclude the wider use of roller dried milk.

The more recent process of spray drying produces a more attractive product, and for this reason the process is extending rapidly in spite of its higher cost and greater technical difficulty. Spray drying has, however, presented more difficult chemical and bacteriological problems. Spray powder comprises regular spherical or oval particles, varying considerably in size (from 5 to 150μ). Particle size is largely a function of the particular atomizer, but even with any one atomizer the range of sizes is very wide. The particles are not solid, but contain pockets of entrapped air sealed in by an outer layer of amorphous lactose glass; the fat is also enclosed within the particle. The air content of the particles is of supreme importance, since this feature largely influences the subsequent keeping quality of the powder and also determines the less important property of " packing density ", i.e. the weight of powder which can be packed into a given volume. In turn, the air content is largely determined by the degree of preconcentration of the milk *before* drying. It is, therefore, desirable to concentrate milk to the highest possible solids content before spray drying—this is also desirable purely for reasons of thermal economy. In general, centrifugal atomizers tend to produce larger particles containing a higher air volume per gram of powder than do jet atomizers, but, on the other hand, the centrifugal atomizer will handle much higher concentrations of solids. The heat treatment associated with spray drying is not very severe, and consequently the product is of good flavour and possesses excellent solubility of 95-99 per cent. The fat globules, although altered, are not destroyed and the reconstituted milk forms a slight " cream-line ". Bacterial destruction is, however, less extensive than in the roller process and hygienic standards of operation are correspondingly more important. The Ministry of Food and the manufacturers of spray powder have (1953) agreed upon a Code of Practice.

Solubility.

Loss of solubility is due to protein changes resulting from heat treatment, and is very marked in the case of the roller dried product. In the case of spray powder, solubility may be affected both during preheating of the milk and during the drying process. Solubility of the resulting powder gradually deteriorates as the milk is preheated above 165° F., although even at 190° F. loss is not serious (in spite of earlier accepted beliefs) and there are other advantages associated with this preheating temperature. Both the temperature of the hot air stream and the time of exposure of the milk to the hot air are important. The maximum inlet air temperature which is desirable is about 170° C., and even this is only possible with rapid, turbulent mixing and rapid removal of the powder from the drying chamber. Exposure of the powder to hot air after drying can have very deleterious effects upon its solubility.

The design of the plant should, therefore, include provision for immediate removal of the powder from the hot air stream, and should employ filter bag collection of as little powder as possible—or preferably dispense entirely with bag collectors by using a train of small cyclone separators.

There is evidence of two types of protein insolubility: (1) That due to heating of the liquid milk, which is an irreversible change. (2) That due to exposure of powder to hot air, which is partly reversible in that the powder shows insolubility in cold water but becomes partly dispersible again in warm water at about 50° C.

A gradual loss of solubility occurs during storage, particularly in the roller dried product. Control of the moisture content is very important, and in spray powder little loss of solubility occurs if the moisture content is maintained below 5 per cent.

Flavour.

Any unpleasant flavours in the raw milk may persist in the dried product. In particular, acid raw milk gives a very unpleasant powder and may prevent roller drying altogether. The acidity of dried milk should not exceed 1·6-1·7 per cent. as lactic acid. Neutralization of acid milk is sometimes practised, but the resulting powder is always of inferior quality.

Keeping Quality. In air at room temperature (60° F.) full cream powder has a storage life of 4 to 10 months and skim powder 6 to 14 months. In the absence of special precautions roller powder has a better keeping quality than spray powder, but the storage life of the latter product has been greatly lengthened by intensive research into gas packing, improved processes of manufacture, and the use of antioxidants. Bacteria never multiply in dried milk and indeed they may gradually die out. Deterioration is mainly chemical in nature and the main factors are oxygen, traces of metals, temperature, and moisture content. The main faults are:

(1) *Oxidised or tallowy flavour.*

Development of a flat flavour, later becoming tallowy and very unpleasant, is the major storage defect of full cream dried milk. This is due to oxidation of the fat, which commences slowly and is followed by a period of very rapid change. The oxygen is first added to the double bonds of unsaturated glycerides to form peroxides; the peroxides then break down to form aldehydes, ketones, and other products. The formation of the intermediate peroxides can be estimated chemically but the later products can only be detected in rather crude fashion by the sense of taste. This defect is not influenced by the moisture content of the powder; this is the only powder defect of which this is true. The major conditions which encourage oxidation are storage at high temperatures and the presence of traces of heavy metals in the powder, particularly copper in excess of 2 parts per million of milk solids. Average milk as received from the farm will give about 1·0 part of copper per million in the powder. The use of copper, tinned copper, or copper alloys must be avoided in the construction of the plant; the ideal material is stainless steel. Spray powder oxidises much more rapidly than roller powder, owing to the air pockets which are sealed up inside the particles. The major problem is, therefore, to increase the keeping quality of spray powder, particularly when stored in warm climates. This may be achieved by gas packing, by high temperature preheating of the milk, and by addition of antioxidants. Gas packing involves sealing the powder in air-tight metal cans, evacuating the container to a very high vacuum (2 to 3 mm. of mercury) and replacing the extracted air with nitrogen or carbon dioxide gas. The process has proved very successful and is the method of perfection; powder may be stored without deterioration for 7 years or longer in tropical climates if the oxygen content of the headspace is reduced to 2 per cent. or less.[4, 5, 6, 7] Even if 2 to 5 per cent. of oxygen is present the keeping quality of the powder is extended considerably. The process does not remove oxygen trapped within particles, but during storage a process of desorption occurs and some oxygen passes into the can headspace. This increase is negligible with roller powder, but may reach 2 to 3 per cent. oxygen with spray powder. In order to attain a final level below 3 to 5 per cent. oxygen it is desirable to attain an original value of only 0·5 to 0·7 per cent. oxygen. It is possible to extract further oxygen by repeating the evacuation and gas filling processes after not less than three days (preferably 7 days) storage, but commercially this is not very practicable. The

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[4] Lea, Moran and Smith (1943), *J. Dairy Res.*, **13**, 162.

[5] Greenbank, Wright, Deysher and Holm (1946), *J. Dairy Sci.*, **29**, 55.

[6] Schaffer, Greenbank and Holm (1946), *ibid.*, **29**, 145.

[7] Haller and Holm (1947), *ibid.*, **30**, 197.

proportion of entrapped air is reduced as pre-concentration of the milk is increased, and is rather higher with centrifugal than with jet-type atomizers. Close control of powder density is important. Gas packing must be undertaken within three days of manufacture of the powder. Alternatively, the powder is sometimes collected in very large bulk storage containers which can be evacuated, the final gas packing in smaller containers being undertaken later. The process is fairly expensive and requires considerable technical skill. A highly efficient vacuum pump, completely gas-tight cabinets, pipelines and valves, and nitrogen of at least 99·7 per cent. purity are required. Elaborate precautions must also be taken to detect and maintain freedom from can leakages as the most minute leak is disastrous.

The temperature coefficient for the rate of development of tallowy flavour is about 2·0 per 10° C. storage temperature rise for full cream spray powder and about 2·5 for full cream roller powder. There is a relation between the peroxide value of the fat, oxygen absorbed, and powder keeping quality, but the values are not constant and vary for different temperatures of storage and different powders, and for air and gas packed powders. Peroxides are only intermediate products which decompose when oxygen absorption is complete. Temperatures of 37° C. and 45° C. are commonly used for accelerated storage tests and the keeping quality of powder can only be assessed satisfactorily by a tasting panel method.

Fishy flavours have occasionally been reported in powders of high moisture content above 3·5 per cent. This defect appears to be due to hydrolysis and oxidation of lecithin to trimethylamine.

A less effective but much simpler method employs a milk preheating temperature of 190° F. before spray drying.[8, 9] The keeping quality of the resulting powder is extended 3-5 times (up to 2 years in air pack), particularly if high grade raw milk is used and the bacteriological condition of the plant is maintained at a high standard. The major factor is the antitoxidant properties of sulphydryl compounds formed from the milk protein at high preheating temperatures. No sulphydryls are produced below 179° F. but the maximum formation is obtained at 190° F. One such compound may be hydrogen sulphide, which is detectable in the milk and sometimes in the powder (depending upon the type of drier), and which may inactivate the copper present in the milk by forming sulphides. High temperature preheating also results in greater destruction of bacteria and deleterious enzymes so that the bacteriological quality of the powder is much improved. The slight loss of powder solubility resulting from high temperature preheating is more than offset by the enhanced keeping quality and greater stability during storage of vitamins A and C and carotenoids; these suffer no greater loss than at lower preheating temperatures. Henry and Kon [10] also conclude that the biological value and true digestibility of the proteins of milk preheated to 190° F. are not inferior to those of milk preheated to 160° F. only. The use of high preheating temperatures has been extended to different makes of spray drying plant with substantially similar results and the method has become a standard one in Britain as a powder keeping quality of two years meets most commercial requirements.[11, 12] In a review of published work Hetrick and Tracy [13] in the U.S.A. also showed that the keeping quality of full cream milk powder depends to some extent upon the raw milk supply and is improved by high temperature preheating, clarification, homogenisation and precondensing of the whole milk, but is adversely affected by increase of storage

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[8] Mattick *et al.* (1945), *J. Dairy Res.*, **14**, 116.

[9] Crossley (1945), *ibid.*, **14**, 160.

[10] Henry and Kon (1947), *ibid.*, **15**, 140.

[11] Findlay, Higginbottom, Smith and Lea (1946), *ibid.*, **14**, 378.

[12] White, Smith and Lea (1947), *ibid.*, **15**, 127.

[13] Hetrick and Tracy (1945), *J. Dairy Sci.*, **28**, 687.

temperature and by traces of copper from plant surfaces. (In Britain clarification was found to be of no significant value.) Considerable improvements are obtainable by gas packing or the addition of antioxidants. In some areas of the U.S.A. gas packing remains in common use. Much experimental work has also been done on the addition of antioxidants such as oat flour, hydroquinone, gum guaiac, ascorbic acid, and ethyl gallate.[12, 14, 15] Most of these impart an undesirable flavour and ascorbic acid is unstable during storage. Ethyl gallate is undoubtedly the most effective and is both tasteless and non-toxic. An addition of only 0·07 per cent. extends powder keeping quality to 2 years without high temperature preheating, while the combination of high temperature preheating plus addition of ethyl gallate extends the keeping quality to 3-4 years. Such additions infringe the preservative regulations in Britain and cannot be used commercially, but they may prove valuable elsewhere.

(2) *True rancidity* produced by the action of lipase upon the butter fat may also occur, but this defect is now less common than formerly. The lipase may be native to the raw milk, or (more frequently) derived from bacteria present in the milk before drying. The defect can be prevented by preheating the milk to not less than 163° F. and by close control of the bacteriological condition of the plant.

(3) A further series of important defects may be classed under the general heading of *protein deterioration*. The major features are loss of solubility during storage and development of " stale ", " cardboard " or " gluey " flavours, and a brownish discolouration. These defects normally occur together and are commonest in skim milk powder. They are accelerated by high storage temperatures and are also greatly influenced by the moisture content of the powder; if this does not exceed 5 per cent. trouble is prevented or much delayed. In addition to careful manufacture, moisture-proof packing is very important and metal containers are always preferable. Extensive investigations have now established the general sequence of chemical changes.[16] Firstly, the amorphous lactose " glass " absorbs moisture to form crystalline lactose monohydrate and the apparent moisture content of the powder decreases. The powder may become sticky and lumpy. Secondly, the casein progressively becomes denatured and insoluble, and at the same time some of the protein combines with lactose to form a protein-lactose compound. At this stage analysis reveals a loss of lactose. Thirdly, the protein-lactose compound appears to decompose, with absorption of oxygen and evolution of carbon dioxide, to form dark coloured products and substances of unpleasant flavour which have not yet been identified. If the first moisture absorption stage is prevented the subsequent stages cannot occur. The reaction is presumed to occur between the aldehyde group of the lactose and an amino group of the protein. A crude compound containing 81·5 per cent. protein and 11·1 per cent. lactose has been isolated. In addition to unpleasant flavours and loss of solubility the powder suffers a reduction of nutritional value. The protein amino group involved is believed to be mainly that of the important amino acid lysine. Losses up to 40 per cent. of the original lysine content have been recorded by Henry *et al.* and replacement of this restores the original nutritional value of the powder. In full cream powder the oxygen tends to react first with the fat and is not available for decomposition of the protein-lactose compound, so that the tallowy decomposition is more usual. On occasions, however, both fat and protein decomposition occur simultaneously in either full cream or skim milk powder. Protein decomposition defects are much delayed by gas packing, but not prevented entirely. Loss of solubility is little reduced, but protein-lactose decomposition is greatly reduced and gas packing offers considerable protection against stale flavours and brown discoloration.

[14] Waite (1941), *J. Dairy Res.*, **12,** 178.

[15] Findlay, Smith and Lea (1945), *ibid.*, **14,** 165.

[16] Henry *et al.* (1948), *JDR*, **15,** 368.

Bacteriological Quality.

Although bacteria present in dried milk die out during storage, their enzymes may remain active in the powder, and various indefinite flavour defects are believed to arise from this cause. Moreover, once the powder is reconstituted in water bacterial growth commences, so that large numbers of bacteria are very undesirable.

Roller powder should contain few bacteria, with an upper limit of 5000 per gram. In addition, the roller drying process in itself is sufficient to destroy all pathogenic bacteria with certainty, although some form of milk preheating is commonly used for other reasons. Bacterial numbers vary widely in spray powder, depending upon the quality of the raw milk, plant cleanliness, the preheating temperature, method of concentration, length of drying run, and seasonal factors. The bacterial flora is a specialised one composed of micrococci, streptococci, corynebacteria and spore-forming bacilli.[17, 18] The drying process itself destroys many bacteria, but is somewhat irregular in its effects and cannot be relied upon to destroy pathogenic organisms. Such destruction depends upon the preheating of milk *before* drying.

There is little correlation between bacterial numbers in the original raw milk and in the finished powder, but there is a close relation between the numbers in the powder and in the preheated milk. High temperature preheating has a very pronounced effect and greatly improves the bacteriological quality of the powder. The process of vacuum evaporation may be a source of serious difficulty. The high degree of concentration which is desirable leads inevitably to the formation of deposits of milk solids in the evaporator, and at the operating temperature of 40°-49° C. many bacteria, particularly streptococci, multiply with great rapidity in such deposits as the run proceeds. Unless this danger is overcome by efficient preheating and close control of plant cleaning and sterilisation, the dried milk will contain rapidly increasing numbers of bacteria as the run proceeds, especially during hot weather.

Poor conditions may be summarised as: (*a*) the use of raw milk of low bacterial standard and containing large numbers of thermoduric bacteria, (*b*) accumulations of stationary batches of hot milk in the plant or of uncooled raw milk awaiting drying, (*c*) inadequate cleaning and sterilisation of the plant, (*d*) inadequate preheating temperature.

Under such conditions, the powder may contain large numbers of bacteria, possibly reaching millions per gram of powder, with pronounced increases during the run and marked differences between winter and summer operation. But with a satisfactory preheating temperature, and a clean, sterile plant, spray powder should contain at the most only slightly larger numbers of bacteria than roller powder, and never more than 20,000 per gram, with only slight increases during a run and no seasonal variations. Even under the best conditions, however, it is desirable to introduce a short break in the run for plant cleaning every 8 to 10 hours, with, of course, a really thorough treatment every 24 hours.

A temperature record should be fitted to the preheater, and the preheating treatment should be equivalent to at least 145° F./30 min. or 161° F./15 sec. if high temperature treatment at 190° F. is not used. Samples of the preheated milk should be submitted regularly to the phosphatase test. (After withdrawing the sample great care must be taken to cool it rapidly, preferably in ice water.) In the roller process the milk is automatically heated to nearly 212° F. during the operation. Daily samples of powder should be examined for colony count, and no powder should be distributed until the bacteriological results are known. If only one powder sample is examined daily this should be taken from the last powder produced.

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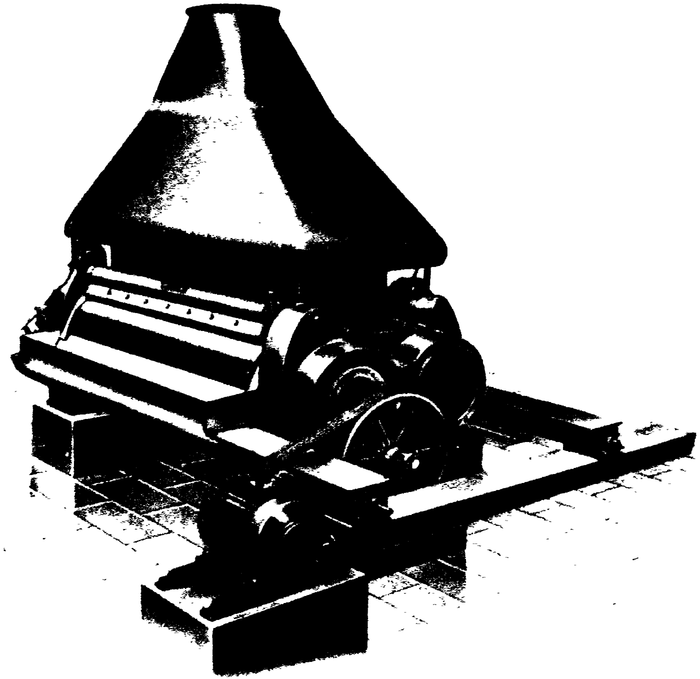
[17] Nichols (1939), *JDR*, **10**, 202.

[18] Crossley and Johnson (1942), *JDR*, **13**, 5.



[By courtesy of N.V. Goudsche Machinefabriek

FIG. MP 4.—*Double Drum Roller Drier.*

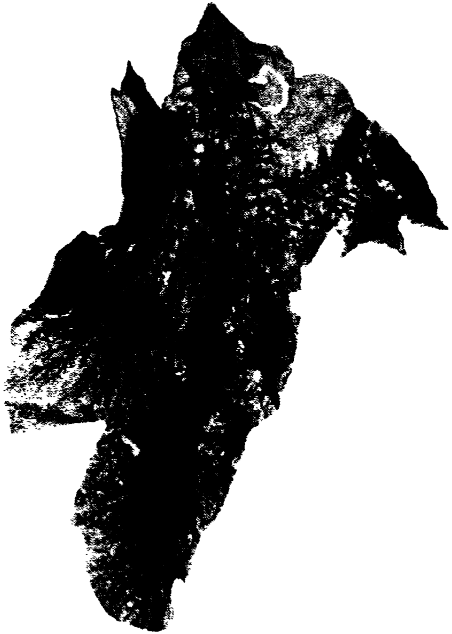


FIG. MS 3.

Mammary Duct System of First Thoracic Gland from an Adult Female Rat.

Recent work [19, 20] has shown how much the bacterial count on milk powder is dependent on technique. ' It is recommended that the powder should be reconstituted in quarter strength Ringer's solution at 50° C. and held at this temperature for 15 min. before plating and that the plates should have the minimum exposure to light before incubation for 5 days at 30° C. and 3 days at 37° C. It is very important that the incubator temperatures, especially 37° C., are accurately maintained. The result of this technique is clearer plates, higher counts, and better replicates, the increase in count being more marked for spray powder than for roller-dried powder. Heat resistant microbacteria grow on plates incubated at 30° C. but fail to grow at 37° C. and it is indicated that any marked difference between the counts at the two temperatures may be construed as failure to maintain the milk pre-heating temperature. The plate count at 30° C. shows the effect of high-temperature preheating, plant-cleaning efficiency, and the quality of the raw milk supply better than the count at 37° C.[8]

Milk powder cakes. Cakes of compressed milk powder were manufactured during 1939-45 to save shipping space and packaging material, but difficultes were experienced with grinding and reconstitution. (*See* Whittier and Webb.)

Dried Sweetened Milk. Dried sweetened milk and dried sweetened condensed milk are products recently developed in America. Typical analytical data are given in Table MP I. The presence of sugar increases the ability and ease of reconstitution. It can be used for chocolate, confectionery and bakery products, as well as for ice cream.

TABLE MP I

(Whittier and Webb)

No.	*Dried product*	*Fat* %	*Milk solids not-fat* %	*Sucrose* %	*Moisture* %
1	Sweetened skim milk .	—	39·0	59·0	2·0
2	" Guigor "—a Swiss milk	16·73	46·01	33·60	3·66
3	Sweetened, part skim .	12·70	65·24	19·85	2·21
4	Q.M.C. requirements .	12·50	59·25	25·00	3·25

Methods of Analysis. For the determination of moisture and fat in milk powder *see A* (1936), **61**, 105, and also Richmond.

Methods for the determination of moisture, fat, protein nitrogen, ash, alkalinity of ash, titratable acidity, bulk density and sediment are given in B.S. 1743 (1951).

Solubility. Methods for determining the solubility of milk powders have been devised by Lampitt and Hughes [21] and Howat *et al.* who also studied the factors which affect the apparent solubility. [22, 23, 24] Spray dried powder gives concordant figures and is generally assessed by a measurement of the volume of sediment after centrifuging the reconstituted powder. This volume is often referred to as the " solubility index " and a method of determining it is published by the American Dry Milk Institute.[25] A method which it is claimed is more sensitive

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[19] Hiscox (1945), *ibid.*, **14**, 175.

[20] Higginbottom (1945), *ibid.*, **14**, 184.

[21] Lampitt and Hughes (1924), *Analyst*, **49**, 176.

[22] Wright (1932), *J. Dairy Res.*, **4**, 122.

[23] Howat and Wright (1933), *ibid.*, **4**, 265.

[24] Howat *et al.* (1939), *ibid.*, **10**, 498.

[25] American Dry Milk Institute (1944), *Bull.* 911, 2nd ed.

to difference between highly soluble spray dried powders is published by Cone and Ashworth.[28]

Roller-dried powder has not been found to give concordant results with any published method. *See* Auto-oxidation; Flavour; Solubility.

Refs.: Cook and Day (1947), *The Dry Milk Industry*, Chicago ; Higginbottom (1953), *JDR*, **20,** 65 (bacteriology) ; Gibson (1952), *DSA*, **14,** 815 (reconstitution) ; Harland *et al.* (1952), *JDS*, **35,** 643 ; Jones and Avery (1953), *IDC*, **2,** 16 ; White *et al.* (1952), *JDR*, **19,** 339 ; Wilcox (1951), *DI*, **16,** 739 (spray drying) ; Parsons and Fraser (1951), *JDR*, **18,** 34 (bacteriology) ; Hibbs and Ashworth (1951), *JDS*, **34,** 1084 (stabilisers and solubility) ; Greenbank and Wright (1951), *JDS*, **34,** 815 ; Decker and Ashworth (1951), *JDS*, **34,** 633 ; Decker *et al.*, *ibid.*, 412 ; Christensen *et al.*, *ibid.* 404 ; Strobel and Babcock (1951), *JDS*, **34,** 167 ; Whitney *et al.* (1950), *JDS*, **33,** 281 (stale flavour) ; Musset *et al.* (1950), *JDS*, **33,** 299 (flavour) ; Higginbottom (1948), *SAB*, p. 18 (microflora) ; B.S. 1743 (1951) (chemical analysis) ; Hällqvist (1949), *IDC*, **2,** 94 (entrapped air) ; Henry *et al.* (1949), *IDC*, **2,** 166 (protein degradation) ; Waite and White (1949), *IDC*, **2,** 259 ; Kruisheer (1949), *IDC*, **2,** 686 (neutralisers) ; Busch *et al.* (1952), *JDS*, **35,** 524 (keeping quality) ; Bianco (1952), *JDS*, **35,** 550.

The Routine Examination of Milk Powder. The following methods are in use in the Government Chemists' laboratory and have been found satisfactory (A. T. Parsons, private communication) :

(1) *Reconstitution*:

Proportions . . .	Separated powder 30 g. to 300 ml. water. Full cream powder 37·5 g. to 300 ml. water.
Temperature of water .	For spray powder : 20° C. For roller powder : 85° C.
Method of mixing .	Place the water hot or cold in a mixing vessel, add the powder and mix with an electric mixer for 30 sec.

(2) *Titratable Acidity.* To 10 ml. of reconstituted milk add 1 ml. of 0·5 per cent. solution of phenol phthalein in 50 per cent. alcohol. As a colour standard, to a second 10 ml. of milk add 1 ml. of bench solution of rosaniline acetate (*see* below). Titrate the 10 ml. to which phenol phthalein has been added with N/9 NaOH solution. If titration is T ml. then T/10 = titratable acidity expressed as grams of lactic acid per 100 ml. of reconstituted milk.

Rosaniline Acetate Solution. (A) *Stock solution.* Dissolve 0·12 g. of rosaniline acetate in approximately 50 ml. of ethyl alcohol (95/96 per cent. v./v.) containing 0·5 ml. of glacial acetic acid. Make up to 100 ml. with industrial alcohol. (B) *Bench solution.* Dilute 1 ml. of the stock solution to 500 ml. with a mixture of ethyl alcohol 95/96 per cent. and water in equal proportions by volume.

NOTE.—Solutions A and B shall be stored in the dark in bottles securely stoppered with rubber bungs.

(3) *Burnt particles, foreign matter and quality.* Place 250 ml. of the reconstituted milk in a tall beaker and allow to stand overnight. Examine bottom of beaker for burnt particles, dirt, etc. Judge comparative solubility and quality of milk from quantity, appearance, and density of deposit ; and from appearance (colour, translucency, etc.) of the liquid above the deposit.

(4) *Moisture.* Dry 5 g. in oven at 100° C. for 5 hr. The oven is fitted with a fan to equalise the temperature.

(5) *Butterfat.* For routine purposes determine by Gerber process as described in B.S.I. Specification No. 696. In cases of dispute use the SPA method (*Analyst*, 1936, p. 110).

(6) *Determination of solubility of roller-dried milks.* (A. T. Parsons, unpublished data.) (*a*) *Reconstitution.* Weigh out approximately 4 g. of powder into a 50 ml. Pyrex boiling tube. Add 32 ml. of water at 50° C. Cork tube and shake for 10 sec. Place in a water bath at 50° C. for 5 min. Shake for 1 min. In shaking make 4-6 double excursions of about 12 in. per sec.

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[28] Cone and Ashworth (1947), *J. Dairy Sci.*, **30,** 463.

(*b*) *Removal of cream* (not applicable to separated powders). Completely fill a centrifuge tube with the hot reconstituted milk and centrifuge for 10 min. in the bowl centrifuge. Cool in refrigerator until the fat is solid but do not freeze the milk. Remove the fat layer with as little milk as possible by running a needle around the edge of fat and then removing it with a spoon shaped spatula. Warm the milk to 20° C. Break up deposit with a rod or wire, and cork tube and shake well until the liquid appears homogeneous.

(*c*) *Determination of total reconstitutable solids.* Transfer about 2 ml. of the milk after removal of the fat and redispersal of the precipitate to a tared covered metal dish and weigh. Let weight of liquid equal L_1. Place covered dish aside for drying with second Total Solids. Centrifuge tube again for 10 min. Pipette about 2 ml. of upper layer into a second covered dish without disturbing sediment and weigh. Let weight of liquid be L_2.

(*d*) *Drying.* Uncover both dishes and place side by side on steam bath until apparently dry. Place in oven at 100° C. for 1½ hr. Cover dishes, cool and weigh.

Let weight of solids corresponding to L_1 and L_2 be S_1 and S_2.

$$\text{Then solubility} = \frac{\frac{S_2}{L_2}}{\frac{S_1}{L_1}} \times 100 \text{ per cent.}$$

$$= \frac{S_2 \times L_1 \times 100}{S_1 \times L_2}$$

NOTES. The centrifuge tubes used have a total capacity of approximately 25 ml. The centrifuge is operated at 2000 rev. per min. and as the radius to the bottom of the rotating tube is about 17 cm., the precipitating force used is approximately 769 g.

(7) *Solubility index.* (Spray powder only.) Measure 20 ml. of the milk reconstituted as described under 1 into a graduated centrifuge tube of about 25 ml. capacity (*see* above). Spin for 10 min. Without disturbing the sediment remove milk within 5 mm. of top of deposit by means of a blow-off apparatus. Refill with water to the 20 ml. mark, stir up sediment, shake well and again spin for 10 min. Read off volume of deposit and record as " Solubility Index ".

Some laboratories, following the lead of the American Dried Milk Institute, carry out a Solubility Index Test on 50 ml. of milk.

(8) *Ash and alkalinity of ash. Ash.* Weigh 2 g. of the powder into a silica or platinum dish of about 50 ml. capacity and heat gently over a flame or at the mouth of the muffle until smoke is no longer given off. Place dish within the muffle and continue heating at 550° C. for 1 hr. Cool in a desiccator and weigh.

Alkalinity of Ash. Ash 2 g. of powder as described above. Add 10 ml. of N/5 HCl from a pipette. Stir with a flat-ended glass rod and break up any particles. Warm carefully with stirring until all ash is dissolved. Cool and add 2 ml. of neutral 40 per cent. $CaCl_2$ solution and 1 ml. of 0·5 per cent. phenol phthalein solution in alcohol. Titrate with N/5 NaOH until a faint pink coloration remains just visible for 30 sec. on the addition of one drop of soda solution. Express the result as ml. of N/5 HCl per 100 g. of powder as received, and also as ml. of N/5 HCl per g. of ash.

MILK PRODUCTION. *See* Agriculture; Breeding; Costings; Feeding; Management of dairy cattle; Milk Marketing Scheme.

Refs.: Nevens (1951), *Principles of Milk Production*, Petersen.

MILK PRODUCTION, SIMPLIFIED METHODS FOR.

Ref.: Mattick (1947), *JSDT*, **1**, 36.

MILK RECORDING. *See* Agriculture, p. 14; Milk marketing.

Refs.: Hendrickx and de Vleeschauwer (1949), *IDC*, **1**, 577.

MILK REGULATIONS 1949. *See* Legal aspects.

MILK SECRETION. Mammary Gland. The mammary gland is a gland of external secretion responsible for the secretion of milk. This gland is an integral part of the female reproductive system.

There is great diversity in the morphology of the mammary apparatus throughout the mammals. The comparative anatomy of the mammary gland has been extensively reviewed by Turner (1939) *The Comparative Anatomy of the Mammary Glands*, Missouri : University Co-operative Store.

In the cow and goat the mammary glands are grouped together in a structure called the *udder*. In the udder of the cow there are four glands, in that of the goat, two. Although the glands are closely compacted within the udder, each is functionally entirely separate and milk cannot pass from one into another.

Structure of Mammary Gland. The mammary gland consists of two main types of structures : (1) the *alveoli* and (2) the *ducts*.

The alveoli or acini are composed of the glandular cells which actually secrete the milk. They are minute, spherical or pear-shaped, hollow structures, the walls of which are one cell thick. The size and shape of the alveoli varies considerably but the diameter is of the order of 0·2 mm. The alveoli are arranged in clusters or *lobules* separated by connective tissue. The alveoli are each connected with the arborescent duct system through which the milk from the alveoli finally reaches the teat. The duct leading from the alveolus is very small and is lined by a single layer of cells. The diameter of the duct system increases, however, as the ducts unite, and the cells lining the duct walls form a double layer. In the cow, the ducts continue to unite until ultimately 8 to 12 large ducts are formed. These open into a large cistern (*the gland cistern*) which varies in size and is easily dilatable. This cistern in turn communicates through a circular opening in its base with the *teat cistern* which communicates with the exterior by the *streak* or *teat* canal which is normally kept closed by a circular muscle (the teat sphincter muscle). The alveoli and duct systems, sometimes termed the gland *parenchyma*, are embedded in and supported by connective and adipose tissue which is collectively termed the gland *stroma*. The milk-producing capacity of the udder depends in the last analysis on the quantity and quality of the gland parenchyma. Udder size is therefore not a reliable criterion for assessing milking capacity since a large udder may contain much stroma but little gland parenchyma.

Vascular System of the Mammary Gland. The disposition of the blood vessels to and from the mammary glands varies with the position and number of glands possessed by the species in question.

In the cow, the blood from the heart reaches the udder by way of the *aorta*, *external iliac artery*, and *external pudic artery*. After passing through the inguinal canal the latter artery is termed the *mammary artery*. As the artery leaves the canal it may give off a branch, the *subcutaneous abdominal artery*, which sends branches into the glands. The mammary artery is the main blood supply to the udder (Fig. MS 1). It divides into cranial[1] and caudal[1] branches which ramify in the udder to form ultimately the capillaries which surround the alveoli and which are in intimate contact with the alveolar cells. The oxygen and the nutrients in the blood pass to the cells by way of the tissue fluids. Minor routes by which blood reaches the udder are the *perineal* and *cranial epigastric arteries*.

After passing through the capillaries the blood reaches the venules ; these continue to unite forming veins. The blood leaves the udder by three routes, which are linked up at the base of the udder by connecting veins forming the so-called venous circle : (1) the *external pudic* vein which lies close to the artery of the same name ; (2) the *subcutaneous abdominal* vein or *milk* vein which emerges from the cranial basal border of the udder and runs just under the skin along the

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[1] " Cranial " = in the direction of the head. " Caudal " = in the direction of the tail.

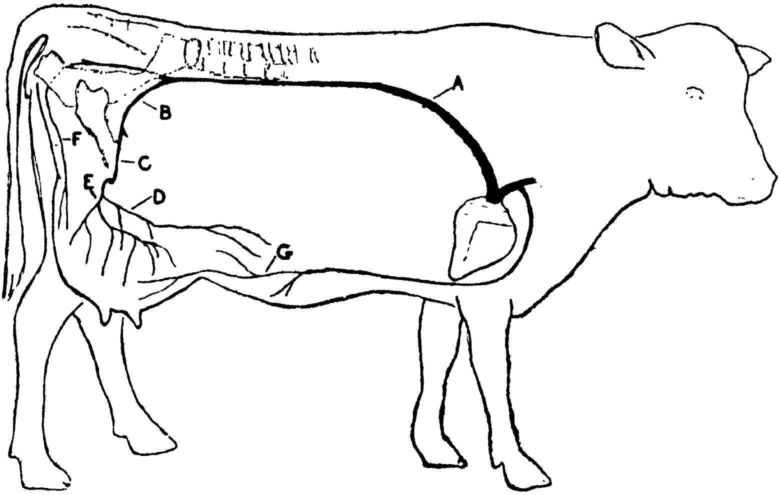

FIG. MS 1.—*Arteries to the Udder.*

A. *Aorta.* B. *External Iliac Artery.* C. *External Pudic Artery.* D. *Subcutaneous Abdominal Artery.* E. *Mammary Artery.* F. *Perineal Artery.* G. *Cranial Epigastric Artery.*

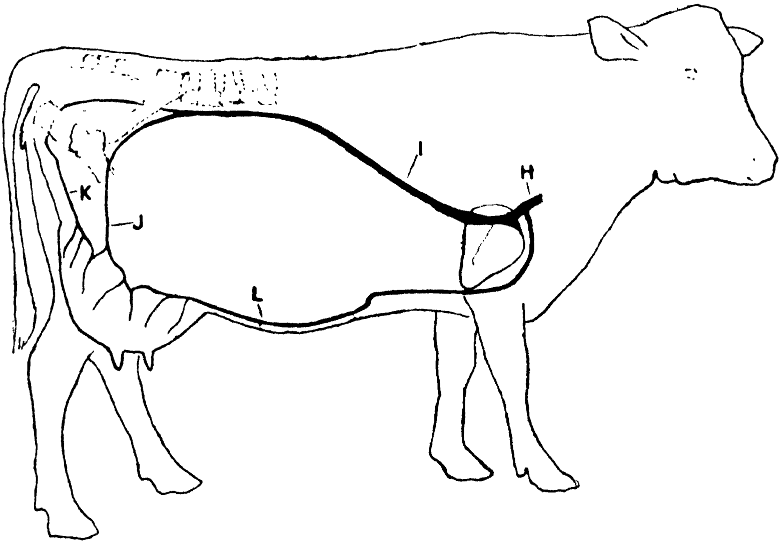

FIG. MS 2.—*Veins from the Udder.*

H. *Cranial Vena Cava.* I. *Caudal Vena Cava.* J. *External Pudic Vein.* K. *Perineal Vein.* L. *Subcutaneous Abdominal Vein.*

ventral lower lateral aspect of the abdominal wall and finally pierces the abdominal wall at a depression (the *milk well*) near the xiphoid cartilage ; (3) the *perineal* vein which leaves the caudal basal border of the udder, turns round the ischial arch and joins the *internal pudic* vein (Fig. MS 2). The blood passing through routes (1) and (3) reach the heart by way of the caudal vena cava, that passing through route (2) by way of the cranial vena cava.

Recent studies in the United States and Russia have thrown doubts on the accepted view that the *perineal vein* drains blood from the udder, and they indicate that the *perineal vein* drains blood from the region of the vulva and vagina *into* the venous circle at the base of the udder.

Lymphatic system. The lymphatic system is subsidiary to the venous part of the vascular system. Fluid in the tissue spaces which originates from the circulating blood may be returned to the capillaries or be removed by the lymph vessels. These begin as capillary-like vessels which unite to form larger channels. Ultimately all the lymph vessels drain into the *thoracic duct* or the *right lymphatic duct* which empty into the venous system cranial to the heart. Interpolated in the course of the lymph vessels are lymph *nodes* which among other functions serve as very efficient filters especially for micro-organisms.

The lymph vessels from all parts of the udder run to the *superficial* and *deep lymph nodes* situated in the neighbourhood of the base of the udder. Lymph vessels may or may not connect the nodes of either side. The lymph is drained from these nodes by 1 to 2 lymph trunks which follow the mammary blood vessels through the inguinal canal to reach further lymph nodes in the pelvis. The lymph ultimately reaches the thoracic duct.

Nerve Supply of Mammary Gland. The mammary gland is innervated both by sensory nerves from the *central nervous system* and by nerves from the *sympathetic system.* In the cow the sensory nerves to the udder are the *cranial* and *caudal inguinal* nerves, the first two *lumbar ventral* nerves, and the *perineal* nerves. The sympathetic fibres reach the gland by incorporating themselves into the trunk of the inguinal nerve. Their origin is uncertain ; they may come direct from the *sympathetic trunk* in the lumbar area or from the *caudal mesenteric plexus.*

There are no secretory nerves to the mammary gland.

Further details of the anatomy of the mammary gland will be found in the following reviews and papers : Turner (1939), *The Comparative Anatomy of the Mammary Glands*, Missouri : University Co-operative Store ; Emmerson (1940-41), *Vet. Ext. Quart. Univ., Pennsylvania*, **41**, Nos. 80 and 81 ; St. Clair (1942), *Amer. J. vet. Res.*, **3**, No. 6, 10-16 ; El Hagri (1945), *Vet. J.*, **101**, 27, 51, and 75.

The Normal Development of the Mammary Gland. The development of the mammary gland follows the same general pattern in all mammals. Six distinct stages can conveniently be recognised.

(i) *Embryonic and foetal development.* The mammary glands develop from the ectoderm of the embryo. Thickening of the epidermis takes place along two parallel lines on either side of the ventral mid-line. Along these *mammary lines*, localised areas of cell proliferation occur forming the *mammary buds*, the number of these corresponding to the number of glands that will develop. These buds proliferate into the underlying mesenchymal tissue forming a conical mass of cells. The cells at the apex of the cone multiply rapidly forming one or more *primary sprouts*, the number depending on the number of individual ducts in the teat of the adult animal. These sprouts penetrate into the mesenchyme and become canalised. They represent the teat and gland cisterns of the fully developed gland. From the primary sprouts develop *secondary sprouts* which represent the beginnings of the duct system. The degree of development at birth depends on the species.

(ii) *Development from birth to puberty.* Mammary growth during this period is confined to the ducts and cisterns and probably parallels general body growth.

In the female rat, however, the growth rate of the ducts may exceed the growth rate of the body before the onset of the oestrous cycle. In the cow and goat the increase in the size of the udder during this period is mainly the result of an increase in the stroma.

(iii) *Development during recurring oestrous cycles.* The first marked development of the duct systems of the mammary gland corresponds with the onset of the cyclic functioning of the ovary. The extent of the development during this period varies in different species and is, to a great extent, dependent on the duration of the follicular and luteal phases of the oestrous cycle. Generally speaking, the longer the luteal in relation to the follicular phase the more complete is the mammary development. In the rat where the luteal phase of the cycle is brief, an extensive duct system is formed but no lobule-alveolar development occurs (Fig. MS 3). In the bitch, however, where the luteal phase is very long, complete lobule-alveolar development and even overt secretion of milk occurs which in some cases may be copious, and the development is comparable to that which occurs in pregnancy. In the heifer and goat there is extensive arborisation of the duct system but it is very doubtful whether true alveolar formation takes place.

(iv) *Development during pregnancy.* At the time of conception the degree of mammary development depends on the species, but in general the mammary apparatus at this time is characterised by the presence of an arborescent duct system spreading out from the base of the teat with a slightly or moderately developed alveolar system. Further duct growth may occur in the early part of pregnancy. The development of the lobule-alveolar system is completed soon after the end of the first half of pregnancy. The apparent further development of the gland is probably entirely due to the onset of the secretory process resulting in an increase in the size of the cells, distension of the alveoli and an increase in the weight and volume of the gland. Evidence of growth involving cell multiplication during the second half of pregnancy is lacking. In the heifer the lobule-alveolar system is generally fully developed by the end of the sixth month.

(v) *Development during lactation.* As already indicated the alveolar epithelium begins to secrete soon after mid-term when further growth ceases. While the alveolar cells may increase in size during lactation there is again no evidence of cell multiplication.

(vi) *Post-lactational involution.* When the withdrawal of milk is stopped due to weaning the young, the alveoli become greatly distended and the whole gland becomes turgid. This state may persist for 1 to 2 days after which the turgidity decreases through the re-absorption of the milk. The alveolar cells degenerate and ultimately the lobule-alveolar system disappears and only the duct system remains. The time required for complete involution varies greatly in different species, ranging from 10 to 12 days in the mouse to 2½ months in the goat. In the cow and goat which are regularly milked, the process of involution is much more gradual. The decline of lactation in the cow is associated with a loss of activity of the alveolar cells in the periphery of the glands.

Mammary development in the male. After birth, mammary growth in the male is usually of a very restricted nature. In the rat the growth of the ducts keeps pace with general body growth and after puberty dense clusters of alveoli appear along the ducts. In the male goat the gland remains very rudimentary throughout life, exceptional cases of lactation in male goats have, however, been recorded.

Hormones Concerned in Mammary Development. While evidence, obtained from transplantation experiments, has existed for some time that the development of the mammary gland was under hormonal control, it is only within the last 25 years that a detailed analysis of the roles played by the various hormones has been made possible by the isolation in a pure or relatively pure state of the hormones concerned.

Ovarian hormones. It is generally stated that oestrogen is responsible for duct growth while the presence of both oestrogen and progesterone is necessary for full lobule-alveolar development. To this generalisation there are, however, several important exceptions ; for in the guinea-pig, goat, and cow, extensive lobule-alveolar development with profuse lactation can be achieved by treatment with oestrogen alone. Whether those glands which are developed by oestrogen are histologically identical with the normal lactating gland has not yet been established. Although both oestrogen and progesterone are necessary for complete mammary development in most mammals, little is at present known of the optimum quantities and proportions necessary for maximal mammary growth.

Anterior-pituitary hormones. While it had been known for some years that extracts of the anterior pituitary could produce mammary development in gonadectomised animals, the anterior pituitary was not considered to play any major role in normal mammary development. Some 14 years ago, however, Turner and his co-workers at Missouri put forward a new theory regarding the mechanism of mammary development which originated from the observation that in hypophysectomised[1] animals oestrogen and progesterone failed to promote mammary development. According to this new concept oestrogen and progesterone stimulate mammary growth *indirectly* by evoking the secretion from the anterior pituitary of two *specific* hormones—Mammogen I and II—which are responsible for duct and lobule-alveolar development respectively. This *mammogen theory* has been the subject of considerable criticism. Not all research workers have found the mammary glands of hypophysectomised animals unresponsive to oestrogen. Furthermore, mammary development can be produced by applying ointments or solutions of oestrogen to the skin overlying a rudimentary mammary gland and, if minimal doses of the hormone be used, only the treated gland will develop, while the neighbouring untreated glands will be unaffected. If oestrogen only acted through the pituitary all the glands should be equally developed. Further research is necessary to clarify the position. It is probable, however, that hormones of the anterior pituitary do play, in conjunction with the ovarian hormones, an important part in mammary development but these hormones need not necessarily be hormones *specific* for mammary development but merely some of the pituitary factors which have other known functions.

Adrenal cortex hormones. The hormones of the adrenal cortex do not appear to play any essential role in mammary development.

Placental hormones. Although there is strong circumstantial evidence that the placenta can secrete both oestrogen and progesterone there is as yet no definite proof that placental hormones are important in mammary development.

Thyroid hormone (*Thyroxine*). The thyroid appears to exert a considerable indirect effect on mammary development by influencing the response of the mammary tissue to the stimulus of the ovarian and pituitary hormones.

Further information on the development of the mammary gland will be found in the reviews by Richardson (1947), *Brit. med. Bull.*, **5**, No. 2/3, 123 and Folley (1947), *Brit. med. Bull.*, **5**, No. 2/3, 130.

Lactation. Confusion has arisen in the past from the use of insufficiently defined terms concerning the phases of lactation. The terms used here are those proposed by Cowie, Folley, Cross, Harris, Jacobsohn and Richardson (1951), *Nature*, **168**, 421. *Lactation* comprises two separate phenomena: (1) *Milk secretion*, and (2) *Milk removal*. Milk secretion may be further divided into a phase of *milk synthesis* occurring in the alveolar cells and a phase of *milk passage* from the cytoplasm of the cells into the alveolar lumen. Milk removal is comprised of the *passive withdrawal* of milk from the gland cistern and *ejection of milk* from the alveoli and small ducts.

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[1] To hypophysectomise = to remove the pituitary by surgical operation.

The Hormones Concerned in Milk Secretion. *Anterior-pituitary hormones.* The importance of the anterior pituitary in milk secretion was first demonstrated when it was shown that extracts of the anterior pituitary could initiate lactation when injected into animals whose mammary glands had been sufficiently developed. Attempts to isolate from pituitary extracts the hormone responsible ultimately led to the isolation of a specific protein termed *prolactin* (also called by some investigators *galactin, mammotropin,* or *luteotrophin*) which was considered to be responsible for the initiation of lactation. (Prolactin has the curious property of causing enlargement of the crop gland of the pigeon and the secretion of the so-called " crop-milk ". This crop response is used in assaying the hormone.) Recent researches have now revealed that prolactin is probably not the only anterior-pituitary hormone responsible for the initiation of lactation and that the *adrenotrophic hormone* also plays a major role. Folley and Young have therefore put forward the concept of a *lactogenic hormone complex* being responsible for the initiation of lactation rather than a single lactogenic hormone. (The initiation of lactation is termed *lactogenesis* and the enhancement of an already established milk yield is *galactopoiesis.*) While prolactin also plays an important role in galactopoiesis there is now evidence that here too other anterior-pituitary factors are involved, for unfractionated extracts of anterior pituitary have a much greater galactopoietic effect per unit of prolactin than preparations of purified prolactin. In ruminants, at least, much of the galactopoietic activity of pituitary extracts appears to be associated with the growth hormone content of the extract (Cotes, Crichton, Folley and Young (1948), *Nature*, **164,** 992).

There is evidence which indicates that the nervous stimuli of suckling may be at least partly responsible for the release of galactopoietic hormones from the anterior pituitary.

Posterior-pituitary hormones. The hormones of the posterior pituitary play no *direct* part in milk secretion but they are now considered to play an all-important role in milk discharge or ejection (*see* Physiology of Milking, p. 736).

Oestrogenic hormones. Oestrogens were at one time considered to have solely an inhibitory effect on lactation but recent experiments have necessitated a modification of this view. While there is ample proof that oestrogens in sufficient doses will suppress lactation in animals with intact ovaries even where milk is regularly withdrawn from the gland, it is also true that in small doses oestrogens can cause both udder growth and lactogenesis. Evidence of these actions is provided by the induction of lactation in virgin heifers by prolonged oestrogen therapy (*see* Hormones in Dairy Husbandry). Associated with the galactopoietic activity of oestrogen is its property of increasing the percentage of solids in the milk (the *enrichment effect*). To explain the apparent anomalous behaviour of oestrogen both in inhibiting and in stimulating milk secretion, Folley has postulated that it acts by evoking or suppressing according to circumstances the secretion of the lactogenic and galactopoietic complexes of the anterior pituitary and that the oestrogen concentration in the blood is the determining factor as to whether stimulation or inhibition of the pituitary secretion takes place.

Hormones of the adrenal cortex. The integrity of the adrenal cortex is essential for full lactation, for in the absence of the adrenals, lactation is seriously depressed or even inhibited. Of the known steroid hormones of the cortex: 11-deoxycorticosterone, 11-dehydrocorticosterone, and 17-hydroxy-11-dehydrocorticosterone would appear to be implicated in milk secretion. The presence of a specific lactogenic hormone of the adrenal cortex (*cortilactin*) has been postulated but its reality has not yet been substantiated.

Hormone of the thyroid (*thyroxine*). The thyroid gland is a regulator of the rate of general cell metabolism and the intensity of lactation is more or less dependent on the level of its activity. Lactation can proceed in the absence of the thyroid, but much less efficiently than normally. The administration of thyroxine or thyroxine-like substances during certain phases of lactation increases both the milk yield and the milk fat (*see* Hormones in dairy husbandry).

Hormone of the parathyroid. Practically nothing is known of the role of the parathyroid hormone in lactation. Removal of the parathyroids in the rat produces a marked depression in the milk yield.

Initiation of Lactation. The secretory phase begins soon after mid-term (*see* Normal mammary development) but copious lactation does not usually occur till after parturition. The exact physiological mechanism controlling the initiation of lactation is still a matter for speculation and further research. One theory is that the high concentration of oestrogen in the blood during the latter part of pregnancy has a direct inhibitory action on the mammary gland and in addition it inhibits the release of prolactin from the anterior pituitary, but with the sudden drop in the oestrogen concentration of the blood at parturition, prolactin reaches the blood in large quantities and lactation is established. Other investigators hold that the formation of prolactin by the pituitary is stimulated by the oestrogen in the blood, but during pregnancy the progesterone-oestrogen ratio is believed to be such that progesterone overrides the lactogen-stimulating effects of oestrogen. The disappearance of progesterone from the blood just prior to parturition allows the oestrogen to act on the pituitary and stimulate the secretion of lactogenic hormones.

The hormones of the posterior pituitary are held to be largely responsible for the uterine contractions at parturition. The view has recently been put forward that at parturition these hormones also cause the *myoepithelial cells* of the mammary gland to contract. The milk is thus expelled from the alveoli into the larger ducts and cisterns as occurs in the normal ejection of milk (*see* Physiology of milking). Full secretion is then maintained by the stimulus of suckling or milking.

Maintenance of Established Lactation. The importance of the suckling stimulus in the maintenance of lactation has long been recognised for when the young are weaned, rapid involution of the mammary gland takes place. It was thought that this was solely due to the cessation of secretion, followed by degeneration of the alveolar cells as a result of the pressure developed inside the alveoli by the accumulating milk. There is now, however, some evidence which indicates that the suckling stimulus may have a considerable influence on the secretion of the galactopoietic hormone complex of the anterior pituitary. The nervous pathways involved and the extent of the influence are as yet undetermined.

There is no evidence whatsoever that the secretory activity of the mammary gland is under direct nervous control, *i.e.* under the control of nerves carrying impulses *from* the autonomic nervous system *to* the gland, as in the case of the salivary glands.

Although the suckling or milking stimulus is of great importance in the maintenance of lactation, some other unknown factor would also appear to be involved for regular and complete milking in the cow and goat will not prevent the gradual decline in lactation and subsequent involution of the gland.

For further information on milk secretion and initiation and maintenance of lactation *see* reviews by Folley (1947), *Brit. med. Bull.*, 5, No. 2/3, 135 and 142.

The Formation of Milk. It was believed at one time that milk was formed as a result of fatty degeneration of the alveolar cells, but this view is no longer tenable. It is now generally accepted that the alveolar cells are long lived and are relatively permanent throughout lactation. The exact changes which occur in the cell structure during milk secretion are still a matter for research but the general cycle of events is approximately known. The secretion first becomes apparent as small globules in the cytoplasm of the cell, these increase in size, coalesce, and collect at the free end of the cell where they are in due course discharged into the alveolus. Whether or not the cell wall is ruptured during the process of discharge is still undecided. (For further information, *see* review by Richardson (1947), *Brit. med. Bull.*, **5**, No. 2/3, 123.)

In addition to the above studies on cell structure (cytological studies), milk formation can be investigated by biochemical methods.

All the materials from which milk is made, as well as those necessary for the energy requirements of the mammary gland, reach the gland in the blood (*see* Vascular system). The three major constituents of milk—milk fat, casein, and lactose—are not present as such in the blood and must therefore be synthesised by the gland from precursor substances in the blood. The identification of these precursors has yet to be completed, and of the intermediary steps in the synthetic processes little is known.

Three main techniques are available for the study of the biochemistry of milk secretion. The first method is to compare the composition of the blood going to the secreting gland with that of the blood leaving the gland (the *arterio-venous* technique). In the cow, samples of the blood going to the udder are obtained by rectal puncture of the arteries which pass through the pelvis on their way to the gland. Samples of the blood leaving the udder are obtained by puncture of the subcutaneous abdominal vein. There are several difficulties and objections associated with this technique: (i) it is necessary to collect the two samples as nearly as possible at the same time and with the minimum disturbance to the animal; (ii) no account is taken of the substances leaving the gland *via* the lymph stream; (iii) the interpretation of the results is further complicated by changes in the rate of milk secretion; and (iv) by the use of blood constituents by the gland for energy purposes. A second method of study, which is really a modification of the first, is the perfusion of the isolated udder with biochemical studies on the perfusing fluid. The third method depends on *in vitro* studies of the metabolic activities of mammary gland slices or mammary mince.

The use of tracer isotopes is proving of great value in the identification of precursors and the intermediary steps in the transformations.

Precursors of lactose. Lactose (milk sugar) is a product peculiar to the cells of the mammary alveoli. The evidence to date indicates that the blood sugar (glucose) is the principal precursor of lactose although other blood constituents may be implicated. It seems possible that glycogen is an intermediate stage in the transformation. Since it has recently been shown that amino acids are deaminated in the mammary gland as well as in the liver, it is possible that carbohydrates may be synthesised from the products of deamination.

Formation of milk fat. It was formerly believed that milk fat arose principally from the triglycerides of the blood, some of the fatty acids being supposed to undergo oxidative degradation in the mammary gland, thus giving rise to the short-chain acids which are a feature of the milk fat of herbivores. Recent work, however, has shown that a considerable proportion of the milk fat must arise by synthesis from small molecules in the mammary gland itself.

Studies on the respiratory metabolism of slices of lactating mammary gland showed that under suitable conditions mammary tissue will actively utilize acetate and glucose *in vitro* with an R.Q. greater than unity. This was interpreted as evidence that mammary tissues utilizes acetate and carbohydrate for the synthesis of milk fatty acids (Folley and French (1950), *BJ*, **46**, 465).

The conclusion that acetate and short-chain fragments derived from carbohydrate are built up into fatty acid chains in the mammary gland has been confirmed by experiments on the living animal involving the use of isotopically labelled precursors. It has been shown (Popják, French, and Folley (1951), *BJ*, **48**, 411), that after injection of acetate labelled in the carboxyl group with radioactive carbon into a lactating goat, radioactive fatty acids could be isolated from the milk. Measurements of the radioactivities of these milk fatty acid fractions showed conclusively that a considerable proportion was formed by condensation of 2-carbon units and the results further indicated that the short-chain fatty acids present in the milk fat of herbivores represent intermediates in the formation of long-chain fatty acids and do not arise by degradation of long-chain fatty acids derived from blood glycerides.

Determinations of the radioactivity of individual carbon atoms of pure fatty acids isolated from the milk of this goat (Popják, French, Hunter, and Martin (1951), *BJ*, **48**, 612) have not only thrown much light on the mechanism by which milk fatty acids are built up from 2-carbon units but have also suggested that β-hydroxybutyric acid is an important precursor of milk fat.

Precursors of milk protein. Relatively little is known of the mechanism of protein synthesis by the mammary gland. Recent work with C^{14}-labelled amino acids indicates that the precursors of milk proteins are the free amino acids of the blood. The phosphorus of casein appears to come from the inorganic phosphate of the blood.

Energy requirements. Experiments with mammary tissue *in vitro* show that it can oxidise carbohydrates (glucose, pyruvate) and acetate.

(For further information see reviews by Folley (1949), *Biol. Rev.*, **24**, 316; (1952), *Biochem. Soc. Symp. No.* 9, 52.

Enzymes involved in milk synthesis. Although the mammary gland is rich in enzymes, little is as yet known of their role in milk synthesis. Only the mammary alkaline phosphatase and arginase have been extensively studied. *See* Enzymes.

Physiology of Milking. If measurements are made of intramammary pressure (*i.e.* pressure in the gland cistern) in the cow, it will be found that there is a gradual rise between one milking and the next, though the curve flattens out somewhat prior to milking as the rate of milk secretion slackens off. A short time after the beginning of milking, however, there occurs a further sudden rise in intramammary pressure. This sudden rise in intramammary pressure, in the absence of which it is impossible to obtain anything like the full yield of milk expected on the basis of previous milkings, is known as the " let-down ". The " let-down " occurs shortly after application of tactual stimuli to the teat by the suckling young or by the milker, or in response to other stimuli (washing the udder with a warm cloth, rattling of milk buckets, etc.) which the animal has come to associate with the beginning of milking.

Only a relatively small proportion of the milk present in the udder at milking time can be drawn off if a tube or cannula be inserted through the teat provided this can be done without causing stimulation of the latter. The milk obtained is that which is present in the gland and teat cisterns and in the large ducts. Milk so obtained is said to be *passively withdrawn.* The greater proportion of the milk, however, is tenaciously held in the alveoli and fine ducts presumably by capillary forces, and it would seem that the " let-down " is the manifestation of some contractile process which squeezes this tenaciously held milk from the alveoli into the larger ducts and cisterns from which it can easily be drawn off during milking. At one time it was thought that the " let-down " was the manifestation of a very rapid reflex secretion of milk by the alveolar cells. This view has no foundation whatsoever, for all the milk obtained from the mammary gland at milking is already present in the alveoli, ducts and cisterns when milking starts. The facts on which the above description of events associated with the application of the milking stimuus are based exist in the literature as widely scattered observations; they have been collected and ably reviewed by Hammond (1936) *Vet. Rec.*, **16**, N.S., 519.

Various theories have been put forward to account for the occurrence of the " let-down ". A good many years ago some authorities had ascribed it to the action of a nervous reflex set into operation by stimulation of the teat. This type of theory has been expounded most cogently by Hammond in the paper referred to above. He visualises a mechanism whereby tactual stimulation of the teat or udder causes reflex contraction of smooth muscle fibres which run in conjunction with the venous vessels leaving the udder. Contraction of this muscular tissue occludes the venous outlets, thereby engorging the udder with blood and setting up a state of what Hammond termed " erection " in the udder tissues. This was supposed to cause the rise in intramammary pressure which is a manifestation of the " let-down ". Hammond pointed out that such a nervous reflex could be conditioned, that is, the animal could be trained to respond by the " let-down " of milk to stimuli habitually associated with milking. Conversely, it could be inhibited by impulses from the brain arising from unfavourable, sensory stimuli such as sudden noises, the approach of an unfamiliar milker, etc.

This theory has had to give ground in recent years before another which assumes that, under the influence of a hormone (oxytocin) reflexly secreted into the blood by the posterior lobe of the pituitary gland, contraction of tissue (believed to resemble plain muscle fibres) surrounding the alveoli takes place. This theory is based on the well-known fact first discovered in 1911, that injection of posterior-pituitary extract into an animal with a cannulated teat causes a marked but transient flow of milk from the teat cannula. This effect, which was once thought to represent a rapid secretion of milk by the alveolar cells, is now known to be due to the effect of oxytocin, present in the extract, causing a mechanical expulsion of residual milk from the alveolar tissues. This was exemplified in experiments in which it was shown that if a cow, which has just been milked out as completely as possible, is given an injection of oxytocin, a further quantity of milk can be obtained. This extra quantity of milk will be compensated for by a reduction in the yield by a like amount at the subsequent milking unless oxytocin is again injected.

Experiments which indicated that posterior-pituitary extract could be concerned in the " let-down " of milk were carried out as long ago as 1915 by Gaines (*Amer. J. Physiol.*, **38**, 285) but the theory that the posterior pituitary plays a physiological role in the milking process has only recently been put forward by Ely and Petersen (1941), *J. Dairy Sci.*, **24**, 211, on the basis of experiments in which it was shown that the " let-down " can be stimulated in an udder which has been denervated. Ely and Petersen further showed that the " let-down " could be inhibited by a fright or by injections of adrenaline, and they postulated that the " let-down " is governed by a balance between the opposing effects of oxytocin and adrenaline.

The main difficulty in the way of acceptance of this theory concerns the type of tissue in the mammary gland which is supposed to contract under the influence of oxytocin. In general, this tissue has been vaguely termed " musculature ", " muscle fibres ", or " myoepithelium " and histological descriptions of it have been confused and uncritical. Recently, however, careful histological studies by Richardson (personal communication) have clarified the position. It has now been shown that there are no true smooth muscle fibres associated with the alveoli, these fibres being confined to the larger ducts. By a special staining technique the so-called myoepithelial cells or " basket-cells " have at last been adequately figured. These cells occur in close proximity with the alveolar epithelium. They are present in large numbers and are so orientated in relation to the alveoli that if they were capable of contracting they would constrict the alveoli and cause the ejection or the " let-down " of the milk. Their contractile properties, however, have so far been assumed only by analogy with the structural appearance of smooth muscle cells and it is yet to be demonstrated that myoepithelial cells will contract in response to oxytocin or any other stimulus.

Once the hormones of the posterior pituitary are secreted into the blood they are rapidly inactivated or destroyed. This fact, if the theory regarding the role of the posterior pituitary in the milking process be accepted, is of considerable practical significance for if milking is not commenced at the time of " let-down " or if the act of milking is not sufficiently rapid the effect of the " let-down " will have worn off before milking is completed and varying amounts of milk will remain in the alveoli and fine ducts. If incomplete milking becomes habitual, the secretory activity of the alveolar cells will be impaired and premature drying off will result.

Research work during the last two years has considerably added to the evidence in support of the physiological role of the posterior pituitary in the milking process. It has been demonstrated both in the laboratories of G. W. Harris at Cambridge and B. Andersson in Stockholm that in lactating animals (rabbits, goats and sheep), kept under conditions which exclude emotional disturbance, electrical stimulation of certain areas of the brain which control the activity of the posterior pituitary caused a milk-ejection response. Moreover, if the nerve connections from these areas to the posterior pituitary were interrupted, the suckling young were unable to obtain milk, as the " let-down " did not occur. In addition, the work of Richardson has now been published in full (*Proc. Roy. Soc. B* (1949), **136**, 30), which describes in detail the distribution and orientation of the myoephthelial cells and shows that their appearance in distended or contracted alveoli is consistent with the assumption that these cells are the contractile elements involved in milk ejection.

It is now evident that the time-honoured term " let-down " is misleading, as it implies that some conscious action on the part of the cow is necessary to hold the milk in the alveolar tissue and that some restraining mechanism is consciously released when milking commences, whereas the " let-down " is a neurohormonal reflex the action of which is involuntary and is not under the conscious control of the cow. It is for this reason that in scientific literature the term *let-down* is being replaced by *milk-ejection*.

(Further up-to-date information on the physiology of milking will be found in the critical reviews by Folley (1947) in *Brit. med. Bull.*, **5**, No. 2/3, 135 and 142). *See* Management of dairy cattle ; Milking machines.

MILK SHED. The area which supplies milk to a given milk-collecting or consuming focal point. The term is analogous to " water-shed ".

" MILK SICKNESS." A peculiar disorder ascribed to the consumption of milk from animals suffering from trembles. It was formerly prevalent in certain districts in the U.S.A. and was considered to be due to toxic substances in the milk derived from certain plants eaten by the cows.

MILK SOLIDS. A term which is used in different senses by different people. To the dairy scientist and dairy technologist it implies, in default of qualification, the whole or total solids of millk, but to the manufacturer it may mean only certain of the solids in milk. Thus to the ice-cream maker it may mean the solids of skim milk, to the processed cheese maker the solids of whey, and to the confectionery manufacturer either the solids of skim milk or of whey. " Milk solids " is a loose term which is best avoided. It is preferable to speak of whole (or total) milk solids, skim milk solids, whey solids, etc.

MILK SOLIDS IN ICE CREAM AND OTHER FOODS, ESTIMATION OF. Apart from those foods where minimum contents of milk solids are laid down by statute, it is often desirable to know what the " milk solids content " is. The exact determination of milk solids in a food of unknown composition is a difficult matter, but with many foods such as ice cream and sausages it is possible to make a fairly reliable estimate of the types and proportions of other constituents. These usually contain only very small amounts of calcium and phosphorus, and as milk is particularly rich in calcium and phosphorus, it is often possible to get a sufficiently accurate knowledge of the milk solids content for practical purposes by estimating the calcium and/or phosphorus. If both are determined, then the absolute amounts in the foodstuff can be used as a double check on the milk solids content, and in addition their ratio calcium/phosphorus will indicate if appreciable amounts of another phosphorus-rich food are also present. The constituent most likely to affect this ratio is soya meal, but this can be detected microscopically by the characteristic " hour glass " cells.

A simple method for an approximate confirmation of the milk solids content indicated by the calcium and phosphorus determinations is to estimate the casein by the colorimetric method described by Hamence and Hart (1951, *A*, **76**, 429).

If a definite estimation of milk solids is necessary, it is customary to make determination of the lactose and/or casein, as these constituents are peculiar to milk. However, it is difficult to free casein from denatured albumin and globulin and also from other proteins such as those in soya and wheat flour. Probably the simplest method for precise confirmation is to determine the lactose, and in practice the most convenient method is by the removal of the fermentable sugars by fermentation, using a large amount of brewer's yeast cells for a short time at a temperature of 25° to 30° C. After precipitation of proteins, etc., the residual lactose can be estimated by any suitable method.

Casein can be separated from other proteins by treatment with 1 per cent. sodium citrate or sodium oxalate. *Ref.:* Jones (1953), *LP*, **2**, 16.

MILK-SOURING ORGANISMS TEST. (i) **Churns.** It is obvious that it is no good insisting on the production of clean milk on the farm if it is tipped into dirty churns. The churn position in many districts is far from satisfactory, and it is only fair that creameries, like producers, should be expected to attain reasonable standards of cleanliness. The following method of testing may be used :

Three churns shall be selected at random and, not sooner than half an hour after being washed, 500 ml. of sterile quarter-strength Ringer solution added. The vessel shall then be rolled between two persons standing 12 ft. apart, five return journeys, *i.e.* 120 ft., and finally inverted to rinse the lid. The rinse solution should be removed with a sterilised dipper. One ml. quantities of the rinse are then removed into each of 3 tubes of litmus milk and the tubes incubated at 37° C. for 48 hr. If not more than 1 tube shows milk-souring organisms (pink clot) the vessel is considered to have passed the test. If 2 out of 3 tubes are positive, the treatment is faulty.

If litmus is not available, 10 per cent. of a 0·04 per cent. bromcresol purple solution may be added to separated milk. Acid (yellow) and clot then indicates a failure. Strong alkalinity also indicates unsatisfactory treatment.

If the rinse-solution is obviously turbid or milky the churn should be condemned. A positive " thumb-nail test " (detection of yellow slime by drawing the thumb-nail or a knife-edge up the inside of the shoulder of the churn) also condemns the churn.

(ii) **Bottles.** The strength of the chain is that of the weakest link. The bottle is an essential link in the chain of modern milk distribution, and dirty bottles, like dirty churns, can easily ruin good milk. Very few bottle-washing machines sterilise the bottles in the strict bacteriological sense as most machines finish with a cold-water rinse ; unless a bactericidal detergent is used the warm rinse and the cold water can with advantage contain 10 p.p.m. chlorine. The following test is suggested :

Three bottles shall be selected at random from the bottle-washing machine and 20 ml. of sterile quarter-strength Ringer solution added to each bottle, which is then shaken 20 times. (The rest of the technique is as for churns.) *See* Bottles, tests for sterility ; Bottle washing ; Churns, cleaning of ; Cleaning and sterilising of plant.

Refs.: LCDP.

MILK (SPECIAL DESIGNATIONS) ORDER, 1936. *See* Legal Aspects.

MILK-STONE. A deposit of calcium and magnesium phosphates, proteins, etc., produced when milk is heated above 140° F. *See* pp. 254, 259, 500.

MILKERS' ECZEMA: *See* Eczema.

MILKERS' NODULES.

Refs.: Cawley *et al.* and Findlay and Haig (1953), *DSA*, **15**, 652, 653.

MILKING. *See* Management of dairy cattle ; Milk secretion ; Milking machines.

Refs.: Dodd and Foot (1947), *JDR*, **15**, 1 (technique); **16**, 14; Dodd *et al.* (1950), *JDR*. **16**, 301 ; **17**, 107 ; Jensen (1949), *IDC*, **1**, 190.

MILKING MACHINES. The mechanical milker was first introduced into Great Britain about the beginning of the present century. Its development was, however, slow, due to the plentiful supply of farm workers and to the reluctance of farmers to try new machines. The War of 1914-18, because of the acute shortage of hand milkers on the farms, gave an unexpected impetus to the adoption of machine milking and since then the milking machine has been coming into general use throughout the country.

The demand for milking machines during the 1939-45 War was so great that the manufacturers had the greatest difficulty in getting installations completed fast enough. It has been said with a great deal of truth that the two most important machines on the wartime food front were the tractor and the milking machine.

At the end of 1947 there were approximately 45,000 herds in England, Wales, and Scotland milked by machine and this number is increasing at the rate of about 5000 machines per year. A feature of the 3 years following the second World War was the steady increase in the number of herds of from 10 to 15 cows, for which machines are being installed. This is not only an indication of the increase of confidence the smaller milk producer has in the efficiency of machine milking, but is in a large measure caused by the great difficulty in getting farm workers to remain at a 7-day week job.

For a full understanding of the action of a milking machine there must be an understanding of the physiology of the udder. Preceding the milking operation there are two distinct and separate physiological processes taking place : (1) The secretion of milk in the udder, and (2) the milk " let-down ". It is the latter which is of special interest to the milking machine user because it is by the stimulation and use of the " let-down " that really satisfactory machine milking is obtained.

In Fig. MM 1 is shown a section of a cow's udder. The entire quantity of milk obtained at a milking is already present as such in the udder tissue at the beginning of the milking. In a state of nature, the sucking action of the calf causes friction and warmth around the teat and this constitutes a stimulus resulting in a conditioned reflex of the udder muscles. About 1 minute later the " let-down " occurs. The reflex referred to causes a constriction of the alveoli and ductules and this forces the milk into the larger ducts and finally through the udder sinus and into the teat. It only remains for the aperture at the tip of the teat to be opened for the milk to be drawn off. This opening process may be done by the sucking calf, by the hand milker, or by the milking machine. It should, however, be fully appreciated that milk cannot pass from the udder tissue to the teat opening unless stimulation has first taken place.

To obtain a full understanding of machine milking, it will be helpful to see what takes place in hand milking and Figs. MM 2, 3, and 4 show the three steps which take place in drawing off milk by hand.

We now proceed to a consideration of the process of machine milking.

The most important part of a milking machine is the teat cup, and it takes many forms. These forms, however, fall into three main groups :

(i) The single-chambered teat cup. With this type the teat is inserted into the single chamber and alternate vacuum and atmosphere is applied to the teat. Milk flows during the vacuum phase and the teat is relieved during the atmospheric phase. This type is not used in Great Britain but several makers in U.S.A. employ the single-chambered teat cup.

(ii) The double-chambered teat cup. In this type, there is a rigid outer metal shell with a rubber lining inside and an annular space between shell and lining. Constant vacuum is applied to the inner chamber. To the annular chamber is applied alternate vacuum and atmosphere. When vacuum exists in both chambers suction is applied to the teat. When atmosphere is present in the annular chamber, the lining collapses on the teat, causing a squeezing action and shutting off the vacuum from the teat. The double-chambered teat-cup can be made with a stretched liner and separate milk tube or it can be a single piece unstretched moulded liner. Both types are in use in Great Britain.

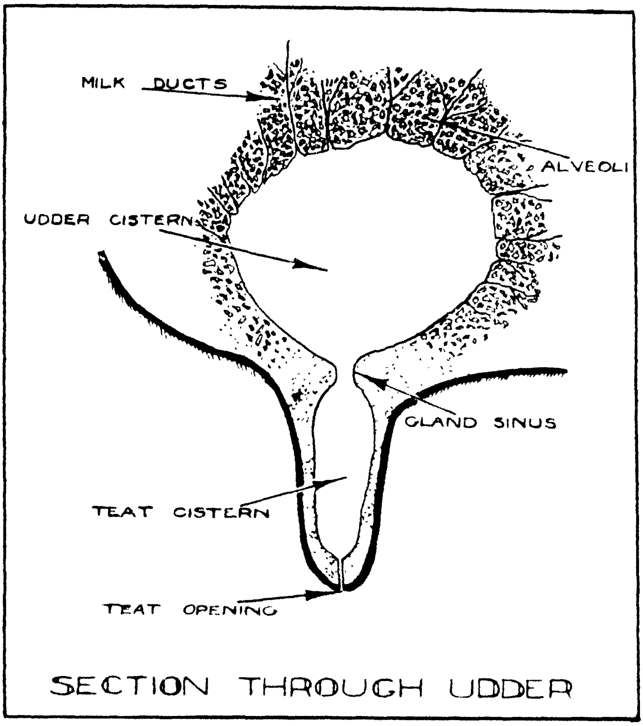


FIG. MM 1.—*Section through Udder.*

(iii) A double-chambered teat cup which functions similarly to (ii) but with the important difference that a third phase is introduced, *viz.* before the liner collapses there is an admittance of atmosphere for the purpose of relieving the teat and removing any congestion that may have been caused by the action of the vacuum. This type is in use in New Zealand.

By far the most popular of the three foregoing teat cup types is (ii). This is the type shown in Fig. MM 5.

A complete milking machine is composed of a number of essential components. These are as follows: (*a*) a vacuum pump with power unit—either engine or electric motor; (*b*) a vacuum controller; (*c*) a vacuum gauge; (*d*) a vacuum system; (*e*) a pulsator; (*f*) a milk container. A great deal of design work has been put into these components and the number of variations produced by manufacturers throughout the world is very great.

Cows may be milked by machine under one of the following conditions:

(i) The cows are tied up in a cowshed and a bucket-type milker used. Each cow's milk is carried to the dairy for cooling and putting into the churn. In this type of machine, the vacuum pump and power unit can be in a fixed position

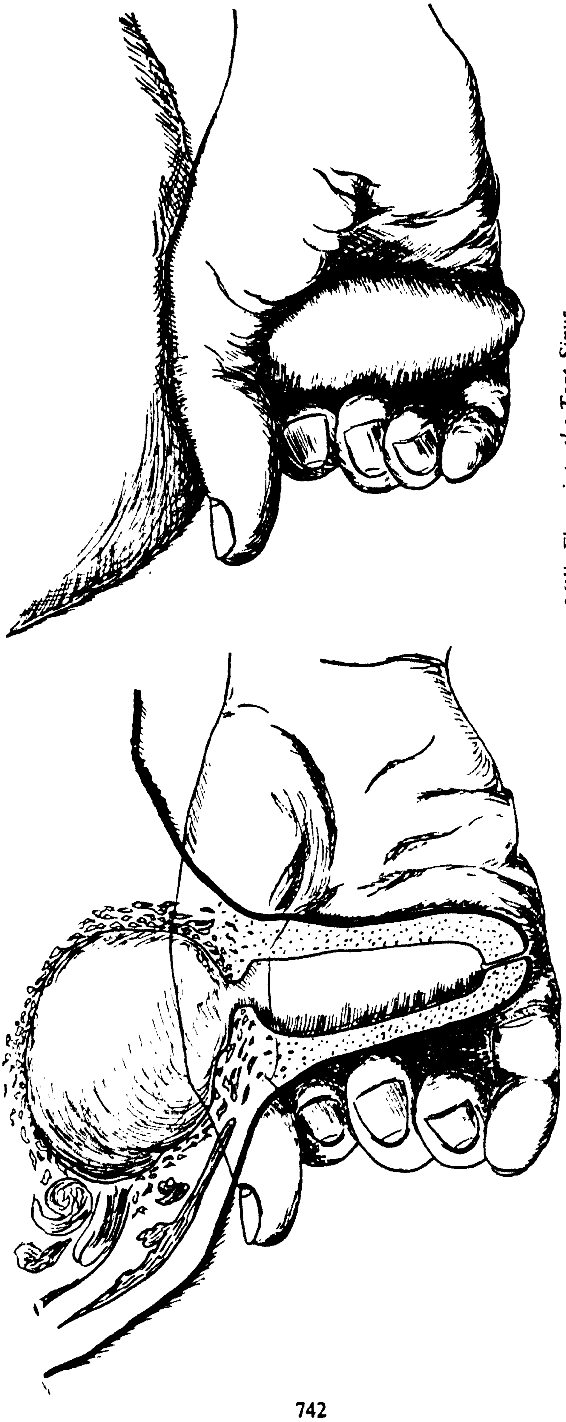


FIG. MM 2.—*Hand Milking. Fingers Loose, Milk Flows into the Teat Sinus.*

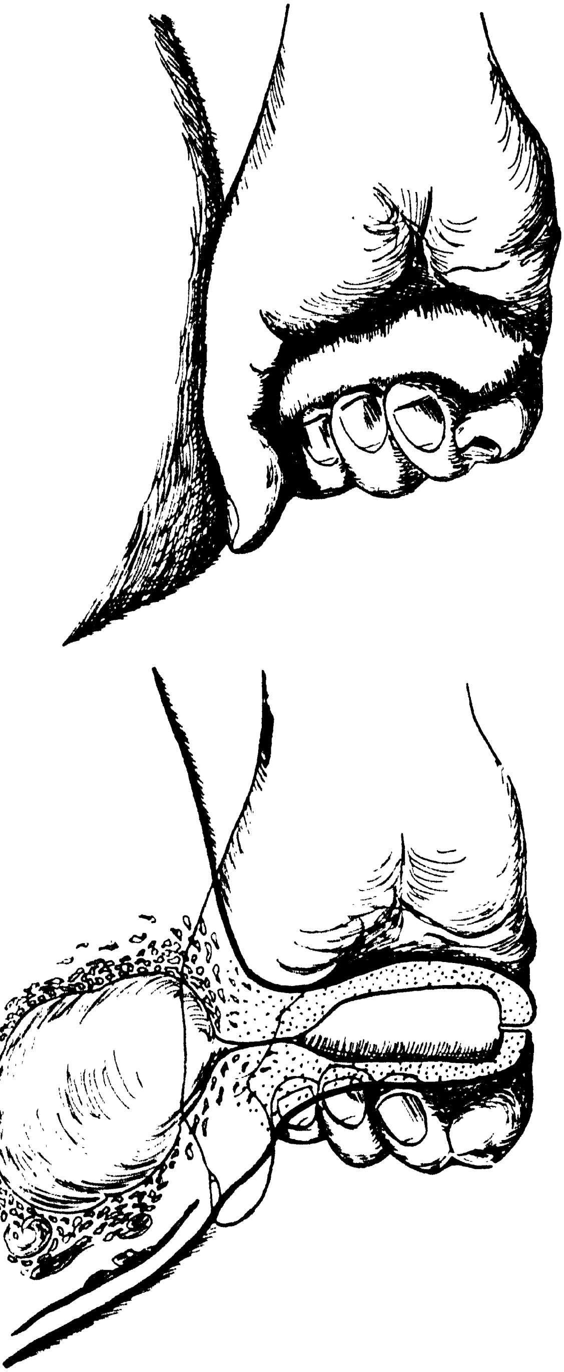


Fig. MM 3.—*Hand Milking. Thumb and First Finger Close off Teat Sinus.*

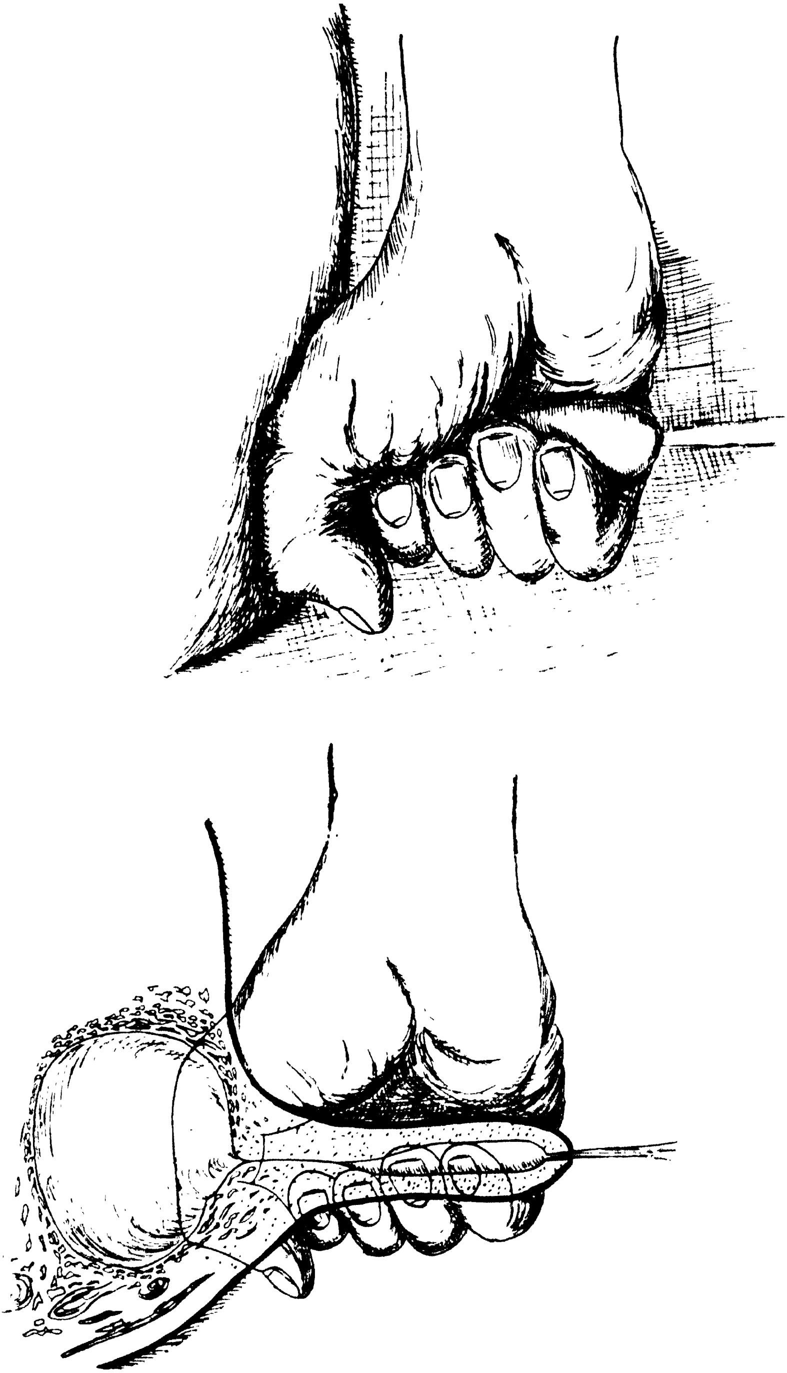


Fig. MM 4.—*Hand Milking. Fingers Progressively Compress Teat and Force the Milk Out.*

and the vacuum pipe line also fixed in a position above the cow's shoulders (Fig. MM 6), or the entire machine can be mobile (Fig. MM 7).

(ii) The cows are kept in loose yards, sometimes referred to as straw yards, cow courts, or open yards.

Adjacent to the yards is a lactory or milking parlour. In the lactory is a milking machine of the type known as an Auto-Recorder (Fig. MM 8). In this type, the cow is milked in a " walk through " milking stall and the milk of each cow enters a pyrex glass container where it is recorded. Then the milk is drawn by vacuum from the container and through a milk pipe to the dairy where cooling and running into churns takes place.

(iii) The cows lie out in summer and come indoors in winter, or, in some districts, cows lie out all the year round. This latter system is used very frequently when there are no cowshed buildings on the farm.

When outdoor machine milking is adopted, then the outdoor mobile Milking Bail is used (Fig. MM 9). This is to a great extent the Auto-Recorder machine made mobile. In some of the simpler types of Bails, however, Auto-Recording equipment is not used. The milk passes into the churn without recording or cooling.

Recent developments. Before Wcrld War II the milking machine was coming into general use in Great Britain. Surveys taken in 1939 showed that there were approximately 25,000 milking machines of both bucket and parlour types in use on farms in England, Scotland and Wales. A farm machinery census taken in 1947 showed that there were then over 45,000 machines. Between 1947 and 1952 there was, however, a tremendous surge of mechanisation of the milking process. The January 1952 Farm Machinery Census disclosed that there were 90,953 milking plants of all types in use in England, Scotland and Wales.

Proceeding parallel with this expansion in numbers of machines there has also been developments in design, and probably the most important development has been the introduction of the " In-Churn System ".

In-churn milking passes the milk direct from the cow to the churn, and this type of milker is being installed in ever-increasing numbers. A great advantage is obtained in the elimination of all intermediate utensils, such as milk vats and surface coolers (Fig. MM10).

In-churn recording of the milk from individual cows is being carried out by means of weighing scales, the scale to be placed at zero after each cow has been milked into the churn (Fig. MM 10).

In-churn cooling can be effected by:

(*a*) The ordinary farm water supply applied to a cooling head of the rotary stirring type. The water comes in under pressure and drives the turbine operating the stirrer. Thereafter the water cools the milk by cascading down over the outside surface of the churn.

Recently another type of cooler head has been introduced in which the motion of the milk agitator is rocking instead of rotating—mixing instead of stirring. It is claimed that this type acts more gently on the milk and avoids the possibility of butter formation in the milk. Moreover, it operates under an almost nil head of water.

In these cooler heads the standard of performance is to cool the churns of milk from 90° F. to within 5° of cooling water temperature in 15 min.

(*b*) The chilled water from a re-circulating refrigerated cooler used in conjunction with cooler heads of the type described at (*a*). The standard of performance for this kind of cooling is to cool the churns of milk from 90° to 50° F. in 15 min. with chilled water at 40° F. (Fig. Ci 1).

(*c*) The churn immersion refrigerated cooler. In this type of cooler the churns of milk are placed in the chilled water tank. The water, but not the milk, is agitated, and this results in a cooling period of as long as 60 min. One advantage of this system is that overnight cold storage is provided.

Combined In-Churn Milking, Recording and Cooling. Equipment is being made enabling the milk to be cooled in its passage from cow to churn. A vacuum sealed spraying head is fitted to the top of the churn and the milk is sprayed on to the inside surface of the churn, and the water on to the outside surface of the churn (Fig. MM 11).

The milk tube from the teat cups is connected to the milk chamber and the water tube to the water chamber of the cooler.

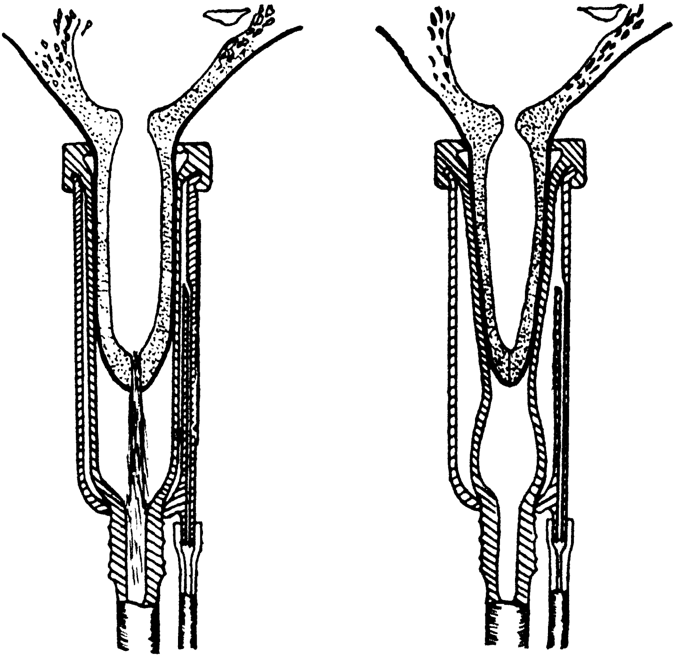


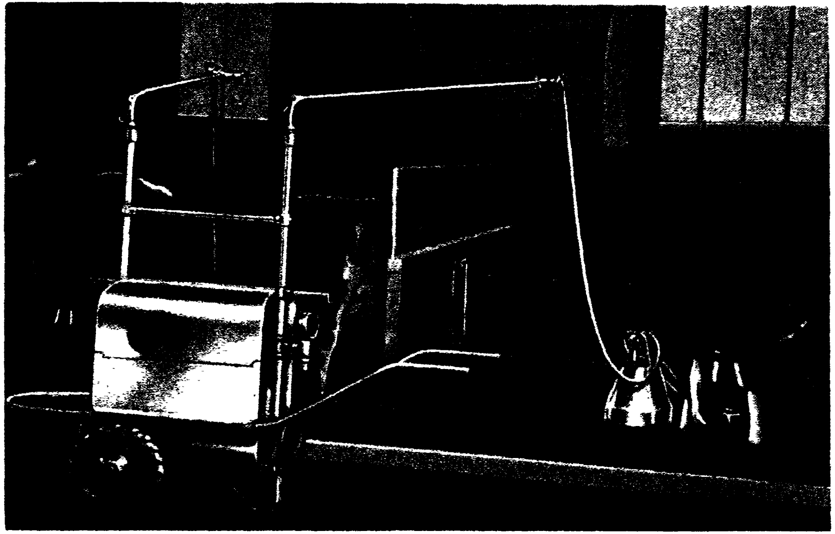
FIG. MM 5.—*Machine Milking.* (*a*) *Suction acts on Teat and Milk Streams Out.* (*b*) *Atmospheric Pressure Squeezes Teat—no Milk Flows.*

The milk is cooled to within 5° of cooling water temperature. If chilled water is used, the milk can be cooled to 50 F., or lower. The water can be conserved by collecting in the tray in which the churn stands and pumping it back to the storage tank.

Refs.: Clough *et al.* (1953), *JDR*, **20**, 375 ; Cooper and Gardner (1953), *JDR* **20**, 340 (deterioration of rubbers) ; Whittleston and Phillips (1953), *JDR*, **20**, 319 ; Dodd (1953), *JDR*, **20**, 301 ; Batt (1953), *NZJA*, **86**, 475 (efficiency) ; Dodd and Foot (1953), *JDR*, **20**, 138 ; Hobson *et al.* (1953), *JSDT*, **6**, 39 (wet storage) ; Whittleston (1952), *JSDT*, **5**, 177 ; (1953), *JDR*, **20**, 146 (fat variations) ; Whittleston (1946), N.Z. Dept. Agric., *Bull.* 260 ; (1948-49), *JSDT*, **2**, 52, 106 and 159; McDowall (1946), *JDR*, **14**, 231 (collection quarter samples) ; "The Mechanisation of Milk Production" (1946), H.M.S.O. ; Dixey (1942), *Open Air Dairy Farming*, Oxford, B.S. 1578 (1949) (rubbers) ; Whittleston (1951), *JSDT*, **5**, 35 (stripping); (1947), Bull. N.Z. Dept. Agric., No. 260; (1948), *JSDT*, **2**, 52, 106, 159; Elms (1948), *JSDT*, **1**, 121 ; Smith *et al.* (1951), *JDR*, **18**, 31 (sows); Baxter *et al.* (1950), *JDR*, **17**, 117 (factors affecting rate); Orr (1919), *D*, Oct.,Nov., Dec. (1920), *Pub. Hlth.*, **33**, 85 (historical).

MILKING MACHINES, CLEANING OF. Although one of the greatest boons to dairy farmers, milking machines can be one of the greatest menaces unless

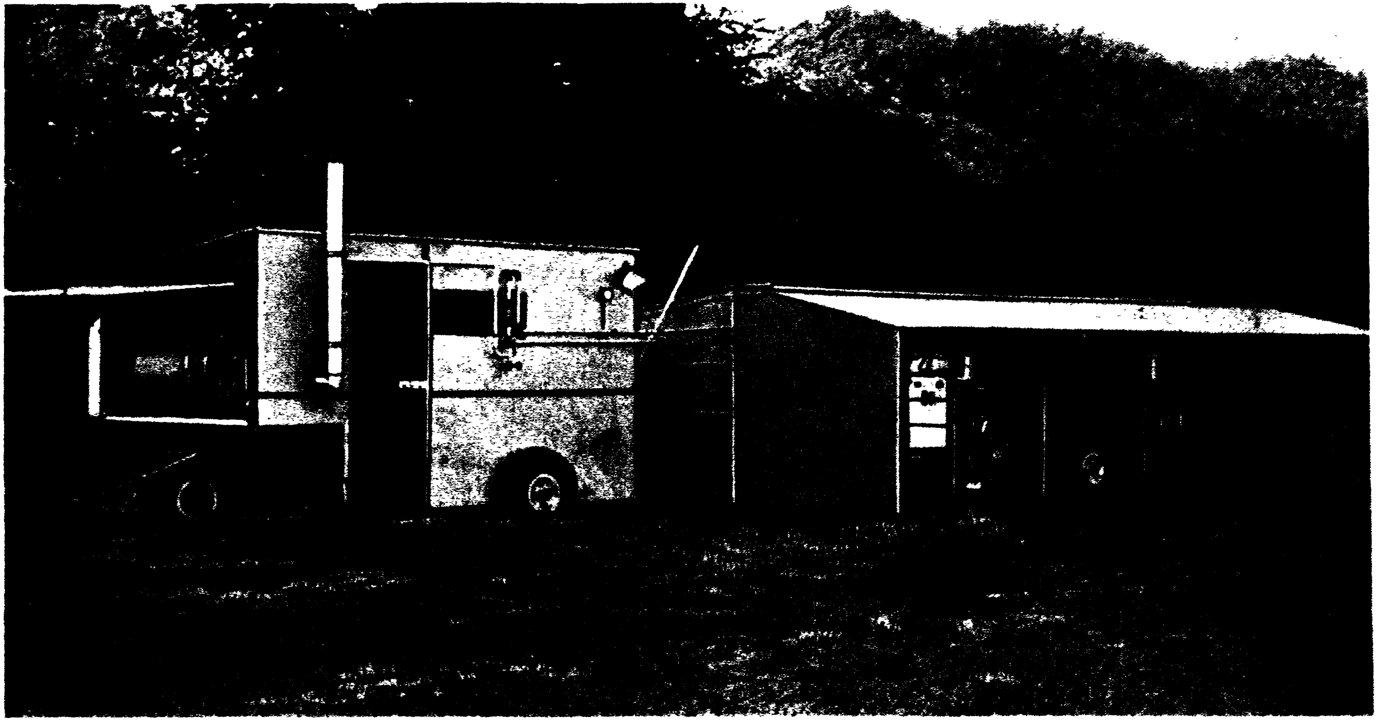
FIG. MM 6.—*Fixed Bucket Milker.*



[*By courtesy of Gascoignes (Reading) Ltd.*

FIG. MM 7.—*Mobile Bucket Milker.*

FIG. MM 8.—*Auto-Recorder Milker.*



[By courtesy of Gascoignes (Reading) Ltd.

FIG. MM 9.—*Outdoor Milking Bail.*

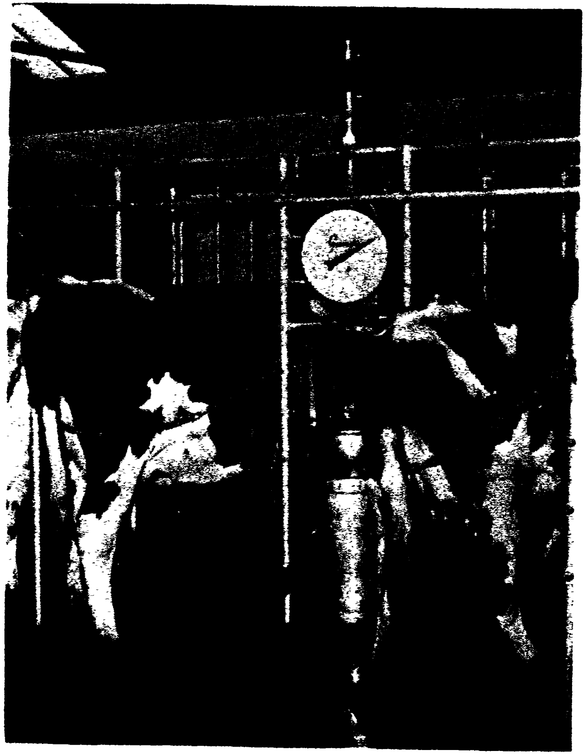
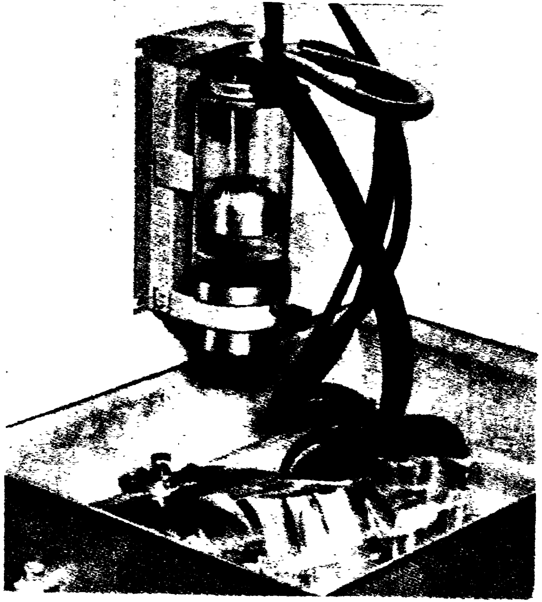
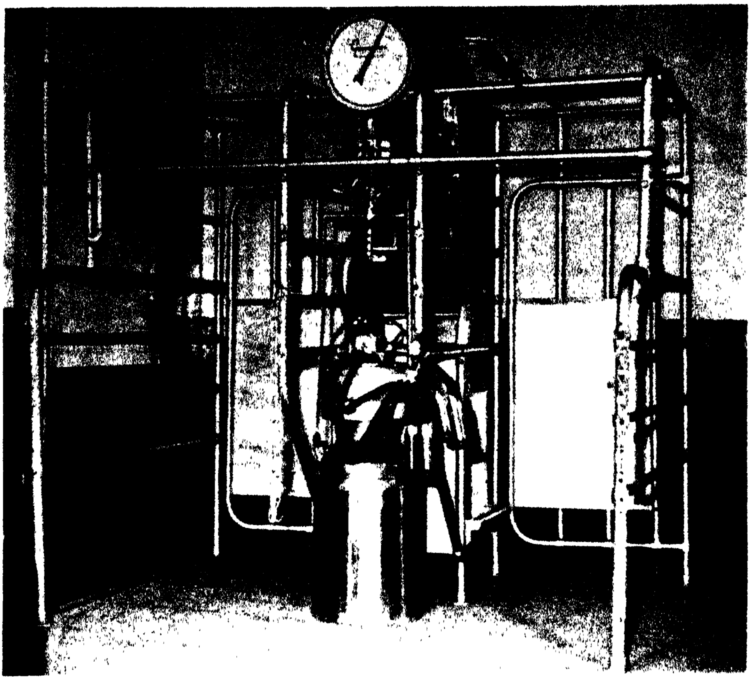


FIG. MM 10.—*In-churn Milking and Recording.*



[By courtesy of Gascoignes (Reading) Ltd.

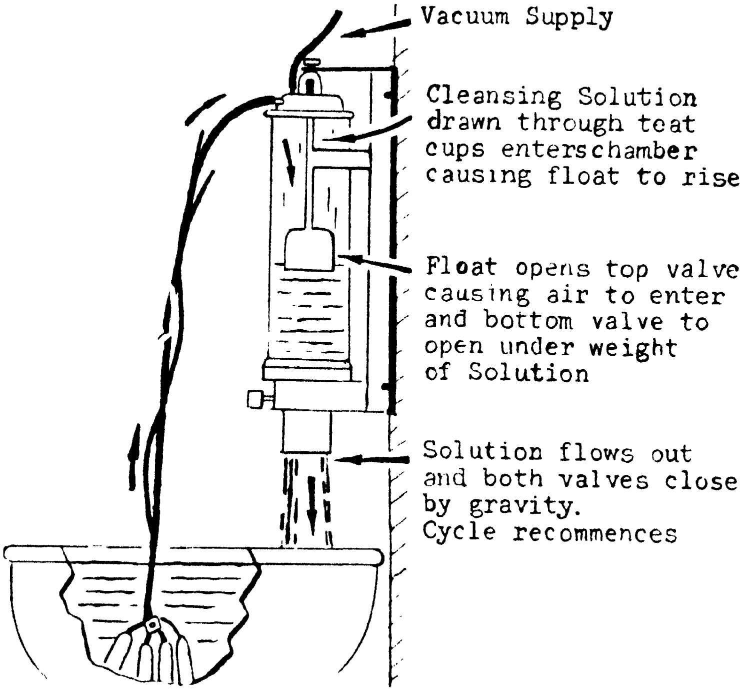
FIG. MMC 1.—*Auto-washer for all Makes of Milking Machine Clusters.*



[*By courtesy of Gascoignes (Reading) Ltd.*

FIG. MM 11.—*A Plant for Combined In-churn Milking, Recording, and Cooling.*

properly handled. Many machines in use are not regularly cleaned and sterilised, with the result that the milk is heavily contaminated at every milking and the chances of infecting healthy cows with mastitis are considerably increased. The deterioration of the liners has been used as an excuse for avoiding steam sterilisation, but Hoy and Neave (1941), *SAB*, p. 39, have shown that "effective sterilisation by steam or hot water does not seriously reduce the life of rubber teat cup liners, and that steam sterilisation is no more destructive than an efficient hot water treatment. Five minutes' jet steaming is effective and allows a sufficient margin of safety in practice." If steaming is impracticable the unit may be treated by first drawing cold clean water through the unit after milking the last cow. The unit is then taken to the dairy and washed in a solution of ¼ per cent. soda ash containing hypochlorite (300 p.p.m. available chlorine). After the usual thorough washing in this solution, rinse in clean cold water containing hypochlorite (10 p.p.m.) and hang up to drain and dry in a clean place. Once weekly dismantle the units and after thorough cleaning sterilise by steam or boiling water. Unless this is done, hypochlorites cannot be relied upon to keep the machine in good condition. Wet storage or soaking overnight in a weak hypochlorite solution is now coming into favour for teat clusters (Figs. MMC 1 and 2). *See* Chlorine; Cleaning and sterilising; Detergents; Hypochlorites.


Vacuum Supply
Cleansing Solution drawn through teat cups enterschamber causing float to rise
Float opens top valve causing air to enter and bottom valve to open under weight of Solution
Solution flows out and both valves close by gravity.
Cycle recommences

[*By courtesy of Gascoignes (Reading) Ltd.*

FIG. MMC 2.—*Auto-washer Showing Flow of Solution.*

Refs.: McKenzie and Lambert (1952), *DI*, **17**, 621; Gardner and Berridge (1952), *JDR*, **19**:, 31; Berridge (1951), *JDR*, **18**, 246 (deterioration of rubbers); Hoy and Rowlands (1948), *SAB*, p. 40 (wet storage); Whittleston (1952), *JSDT*, **5**, 177 (rubbers); Rowlands *et al.* (1949), *IDC*, **1**, 215; Piraux *et al.* (1949), *IDC*, **1**, 221.

MINERALS. Cow's milk is especially rich in potassium, calcium, and phosphorus and so is especially valuable in human nutrition for these elements. Correspondingly, milch cows deplete the soil of these elements which must be replaced by heavy manuring with phosphate, potash, and lime. *See* Agriculture; Ash; Constituents; Feeding; Nutritive value.

Refs.: Davies; Wallace (1951), *The Diagnosis of Mineral Deficiencies in Plants by Visual Symptoms.*

MINOR CONSTITUENTS. *See* Constituents ; Trace elements.

MISCIBILITY. The ability of two materials, especially two liquids, to mix.

MOISTURE. The moisture content of dairy products is of the greatest scientific and economic importance because *free* moisture controls bacterial growth and so keeping quality. The free moisture may be only a proportion of the total moisture and with complex systems like cheese and milk powder, it is not possible to measure accurately the free moisture—all that can be done is to heat the material to a given temperature (usually 100° to 103° C.) for a given time or until constant weight is obtained.

In Dean and Stark's method for moisture determination, the material is distilled with an immiscible liquid such as toluene and the water measured volumetrically. For Tate and Warren's modification, *see* (1936), *A*, **61**, 367.

Moisture may also be determined by the Karl Fischer method (Stuckey (1953), *LP*, **2**, 542).

Butter must legally not contain more than 16 per cent. moisture, and milk powder rapidly deteriorates if the moisture much exceeds 3 per cent. High moisture cheese also develops taints easily and condensed milk shows sedimentation if the water content is high. *See* Butter ; Cheese ; Condensed milk ; Milk powder ; Stability.

Refs.: Milk Testing; Richmond; Mason (1939), *Fat, Total Solids and Moisture*, London; Kumetat and Demmler (1949), *M*, **4**, 111 (rapid methods); Jax (1949), *IDC*, **2**, 777.

MOLAR. A quantity referring to the molecular weight of a substance, *e.g.* 1 *g. mol.* is the molecular weight in grams ; a *molar solution* is the molecular weight in g. per l. of solution.

MOLECULE. The smallest particle of a compound which can possess the properties of that substance.

MOLYBDENUM. *See* Trace elements.

MONEL METAL. A corrosion resistant alloy of the composition 67 per cent. nickel, 30 per cent. copper, 1·5 per cent. iron and traces of other metals. Copper-containing alloys should not be used for purposes where they come into contact with milk.

MONILIA. A genus of moulds usually forming a pink or red pigment. *See* Moulds.

MORNING MILK. This is almost invariably lower in fat than evening milk because of the longer interval between p.m. and a.m. milkings.

Morning milk is usually of poorer keeping quality than evening because utensils are not always sterilised after afternoon milking and conditions are often difficult, *e.g.* artificial light, etc. However, as it reaches the buyer at a relatively earlier time, *e.g.* after 4 hr. instead of 18 hr. as for evening milk, its bacteriological quality *at the time of reception* is usually better. *See* Collins' rule ; Composition, factors affecting.

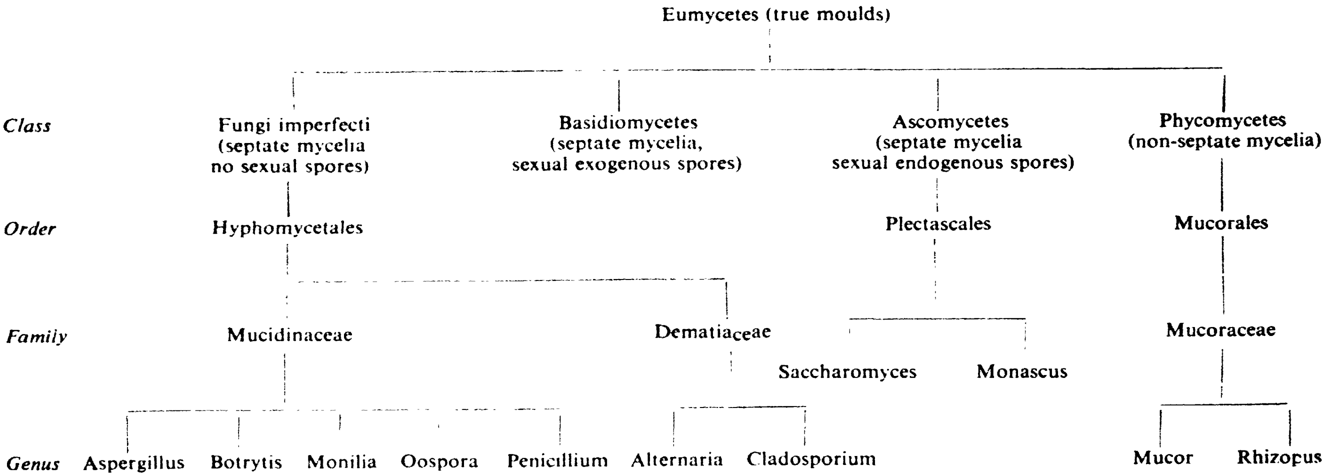
MORPHOLOGY OF BACTERIA. *See* Classification ; Coliforms ; Lactic acid bacteria ; Thermoduric bacteria ; Thermophilic bacteria.

Refs.: Bergey ; Chalmers ; Cunningham ; Wilson and Miles.

MOULD POWDER. Cultures of mould spores used for " starter " for blue-veined cheese. *See* Cheese, pp. 199 and 201.

TABLE Mo I

CLASSIFICATION OF FUNGI



MOULDS. Moulds are, like bacteria, ubiquitous and grow especially well in humid atmospheres and on acid sugar-containing liquids. They are included in that group of lower plants known as *Thallophyta* (*see* Micro-organisms) being without chlorophyll, the green colouring matter of the true plants, and having no differentiation of stem, leaves, or roots. In dairying, moulds are of interest because they are the causative organism of " blueing " in Stilton and similar cheese, and they also cause faults in badly-made, hard-pressed cheese and in butter.

Moulds may be classified as in Table Mo 1.

See Antibiotics; Butter, p. 131; Cheese, p. 168; Media, p. 672; Stability.

Refs. : Prescott and Dunn ; Smith ; Hawker (1950), *Physiology of the Fungi;* Brian (1952), *LP*, **1**, 242; Galloway (1950), *Applied Mycology and Bacteriology*, London; Gilman (1945), *A Manual of Soil Fungi*, Iowa; Ainsworth and Bisby (1950), *A Dictionary of the Fungi*, London; Funder (1953), *Practical Mycology*, Oslo.

MOULDS, PREVENTION OF GROWTH OF. The simplest and best way of preventing mould growth is to keep the humidity down and exclude air from the interior of dairy products such as cheese. The surface of dairy produce may be swabbed with 8 per cent. propionic acid, and wooden shelves may be treated with zinc chloride.

MUCOR. A mould which produces citric and oxalic acids. *See* Moulds.

MULE. *See* Mammals.

MUNSTER. *See* Cheese, p. 197.

MUTANT. An organism which has developed properties different from those of the parent strain or culture. When these are concerned with heat resistance, pigment production, etc., the mutants may be the cause of faults in dairy products. *See* Cheese, p. 168 ; Classification ; Stability ; Sterilised milk.

Refs. : Wilson and Miles.

MYCELIUM. The vegetative, germ-tube, or filament part of moulds. Spore-bearing hyphae or " fruit-bodies " are formed from the mycelium. *See* Moulds.

MYCOBACTERIUM. This genus of the higher bacteria is characterised by its acid-fast properties (p. 235) and tendency to branching. Usually its members are slender rods, irregular in form, Gram positive (p. 493), non-motile, non-spore-forming and aerobic, and frequently pathogenic for man and animals. These are three broad groups : (i) *Mycobacterium tuberculosis* (T.B.) (human, bovine, and avian variants), etc. ; (ii) *Myco. leprae* (Hansen's bacillus), etc. ; (iii) *Myco. paratuberculosis*, or Johne's bacillus, etc. *See* Classification ; Diseases ; Tuberculosis.

Refs. : Bergey ; Gaiger and Davies ; Miller ; Wilson and Miles ; Edson (1951) *BR*, **15**, 147 (metabolism).

MYNOT-PLUMEY PROCESS. A single-roller drier fed by a smaller, unheated roller which is partially immersed in milk beneath it. *See* Milk powder.

MYRISTIC ACID. *See* Fatty acids.

MYSEOST. *See* Cheese, p. 197.

NATIONAL INSTITUTE FOR RESEARCH IN DAIRYING * (SHINFIELD, NEAR READING, BERKSHIRE). Historical. University departments for the teaching of agricultural science as a special subject were established in Scotland (Edinburgh) in 1790 and in England (Oxford) in 1796. In courses held at these universities and later at other agricultural training centres founded during the nineteenth century, dairy husbandry had been studied, whilst a number of enterprising dairy herd owners had made more or less successful attempts to improve practical milk *production*. It was not, however, till 1888, with the establishment at Aylesbury of the British Dairy Institute—an organisation founded to give technical instruction in cheese and butter making—that the scientific basis for the improved *handling* of milk and for the rational making of dairy products began to receive serious consideration in Great Britain.

At that time, there was little except the patchy background of slowly acquired and often apparently contradictory rule of thumb knowledge as a basis for any kind of dairy improvement. The effects of balanced feeding, cowshed hygiene and other factors on milk yield and quality were hardly realised. Although in the eighteen-eighties something of the order of two-thirds of the total production of milk was already being sold for consumption in the liquid form, there were always substantial losses between producer and consumer, and in the consumer's house, especially during the warmer months of the year, as a result of souring, the real reasons for which were subjects of speculation. Cheese, butter and other dairy products often suffered from defects of unknown or uncertain origin.

Apart from the work on soils and fertilisers begun at Rothamsted in the eighteen-forties, planned experiment in most branches of agricultural science, particularly in dairying, had received surprisingly little attention in Great Britain before the early years of the present century, though countries abroad were already carrying out effective research in some of these fields.

As a result, the rate of the practical application to British agriculture of new knowledge and new discoveries was lagging seriously behind. It became more and more obvious that national action to provide means and facilities for research in a number of branches of agricultural science was both necessary and urgent, and under the Development and Road Improvement Funds Act passed in 1909 Development Commissioners were expressly charged with this duty.

Sir Daniel Hall, one of the first Commissioners appointed, stated that one of the main objects of the Commission was the establishment of agricultural research institutes " each charged with the fundamental research dealing with one particular branch of the subject ". Several such institutes, usually in close association with a university or other senior teaching centre, were set up by the Commissioners during the next 2 or 3 years. The one to deal with dairy research was established in 1912 at Reading, a town situated in the midst of a progressive dairying district and having an active University College (now the University of Reading), where dairy teaching was taking place, the British Dairy Institute having been transferred there from Aylesbury some years previously.

Beginning modestly with a staff of two—a bacteriologist and a chemist—with an income, to cover all expenditure, of under £2000 per annum, and provided with three attic rooms and a cellar in what had been a private house close to the University, and with neither farm nor dairy, the Institute was, however, most fortunate in its first appointments. The bacteriologist, R. Stenhouse Williams, a medical man who had been a lecturer in his subject at Liverpool

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* *See* also article on Research, Dairy, p. 916.

University, and the chemist, John Golding, with an extensive training in analytical and agricultural chemistry, who came from the Headship of the Chemistry Department of the Midland Agricultural College (now the Department of Agriculture of the University of Nottingham) set about, with great energy, the task of building up from scratch an active dairy research unit.

Establishment of the Institute at Shinfield. In spite of the dislocation caused by the 1914-18 War, *ad hoc* research, concerned with the immediate problems of the dairy industry under war-time conditions, continued. Whilst the war held back the material expansion of the infant Institute, it gave the staff much additional first-hand information on the causes of several of the industry's technological troubles, both on the production and on the distribution side. It also enabled Williams to interest powerful friends in their solution, which depended not, in so many cases, on the application of existing knowledge, but on the acquisition of entirely new experimental data. It soon became abundantly clear that such data were practically unobtainable without facilities of an entirely different order from those afforded by three attics and a cellar, and after the war, with the help and support of Lord Elveden (later the second Earl of Iveagh) and other friends, the Shinfield Manor Estate of some 350 acres was purchased and the foundation stock for a herd of dairy Shorthorns was acquired. Laboratories were set up in the old Manor House and research began at Shinfield in 1923. Three departments, Bacteriology under Stenhouse Williams, Dairy Husbandry under James Mackintosh, and Dairy Chemistry under John Golding, were established.

Early Activities of the Institute. The period from 1924-32 (Williams died in 1932) was one of steady development during which the Institute, mainly through its researches on clean milk production, became well-known in the industry. The Institute was also becoming more conscious of the serious gaps, both in basic and in specific bacteriological, physiological and nutritional knowledge which handicapped a fruitful approach to so many dairy problems. During this period, in addition to work directed to find and demonstrate the simplest means for regular *production* of clean raw milk of good keeping quality, the retailers' difficulties in handling and *distribution* were investigated and the main sources of bacterial contamination tracked down. Methods of chemical analysis of milk and dairy products were re-examined, and some of them improved, and experiment was begun to assess the effect of pasteurisation on the nutritional value of milk. The causes of deterioration, both bacteriological and chemical, of butter, cheese and other milk products received much careful study, with results valuable to the industry, whilst the origin of certain objectionable taints and flavours in liquid milk was clearly established.

Development since 1933. Since 1933 the scope of the Institute's activities and usefulness, the foundations for which were so well laid by the original staff, has steadily extended. As regards accommodation, the Institute library, which is not only of key importance for the Institute's work, but a dairy industrial asset of the first magnitude and much used by scientific workers from outside the Institute, was rehoused in 1934 in a building erected for the purpose, the Stenhouse Williams Memorial Library. From the decrepit, inconvenient and generally unsuitable Manor House, chemical, nutritional and physiological investigations were transferred in 1938 to a new laboratory building, and some provision was also made for dairy machinery testing. Further building developments, in an advanced stage of planning in 1939, were inhibited by the outbreak of the World War. A small extension to the Machinery building was permitted in 1945, and Arborfield Hall farm was purchased in 1947.

The pressure on the existing buildings, after the end of the war, rapidly became intolerable, and in absence of any more suitable alternative a number of second-hand nissen huts, previously forming part of an Army camp, were purchased, re-erected at Shinfield, and provided with the necessary equipment and services to meet some, at least, of the most urgent needs for laboratory and workshop space. (This temporary accommodation will, in due course, be replaced by more suitable permanent buildings.)

An extension to the Memorial Library (in which the Commonwealth Bureau of Dairy Science is also housed) was completed in 1949, thereby almost doubling the accommodation previously used for library and bureau purposes and providing room for a statistical officer and his staff.

Present Organisation and Activities. To meet the varied problems of the present-day dairy industry and to carry out the basic research without which the Institute would soon lose its ability to deal even with the *ad hoc* problems, there are at present (1954) eight research departments—Husbandry, Feeding and Metabolism, Physiology, Bacteriology, Chemistry, Physics, Engineering and Nutrition.

The *Husbandry* department manages two dairy farms—Church Farm, Shinfield, and Hall Farm, Arborfield, about a mile apart. Each farm has under cultivation about the same area (350 acres) of, mainly, rather light land. The present dairy herd, which consists of some 400 bovines in all, is made up of pure Shorthorns, Guernseys and Friesians, with some miscellaneous identical twins. All are used for various types of experiment by the Institute departments. Research in the Husbandry department is primarily concerned with problems of dairy farm management—the main fields of interest at present being cropping (including the management of grassland and of other fodder crops) for milk production, and cowshed technique in relation to the efficiency of machine milking and the prevention of udder disease. The Bacteriology and Engineering departments collaborate with the Husbandry department in much of this research.

The *Feeding and Metabolism* department deals mainly with the fundamental problems of the feeding and nutrition of *dairy* stock. At present, the factors affecting the efficiency of food utilisation by bovines, the significance of colostrum and the effect of specific changes in the diet of lactating cows on milk yield and composition are the main subjects of investigation. A good deal of the work of this, as of every department of the Institute, is in collaboration with other departments.

The *Physiology* department is concerned for the most part with the basic physiology of mammary growth and lactation in the ruminant, and the hormonal control of those processes. It is also greatly interested in the biochemical changes associated with the formation of the specific milk constituents, and the detailed mechanism of " let-down " of milk.

The work of three departments just mentioned is of main application to the cow as a milk producer. The other five departments, whilst all concerned in part with the dairy cow, are equally involved with problems of milk distribution and manufacture.

The *Bacteriology* department deals with the perennial problem of the improvement of the keeping and hygienic quality of liquid milk, both raw and heat-treated. The taxonomy of the streptococci (a subject quite fundamental both in dairy work and in the clinical field), cheese ripening and cheese starters, butter quality, the prevention of udder disease and the rôle of the intestinal flora in ruminant nutrition, are other subjects studied in this department.

In the *Chemistry* department, the main interest lies in the compositional quality of milk and of dairy products, particularly the analytical methods for determining such quality and the factors (such as breed and nutritional status of the cow, season of the year, methods of manufacture and storage of dairy products), which affect it.

The *Physics* department is mainly concerned with the physical properties of milk and dairy products, including electrical conductivity, ultra-violet and infra-red absorption spectra and flow properties in relation to the control and prediction of desirable qualities in the finished product. It is also experimenting on the relationship between the flow properties of the cervical secretions of the cow and the stage in the ovarian and reproductive cycles.

The *Dairy Engineering* department, established in 1946, is concerned with performance tests of dairy machinery and equipment, both official for eventual publication and confidential, the latter type of test being paid for by the manufacturers. Special apparatus is made here for other departments of the Institute; research is also being carried out on new types of dairy machinery.

The *Nutrition* department deals with the food value of milk and milk products to the consumer and investigates the origin and magnitude of possible changes in such nutritive values. This department was the first to show clearly, in 1935, after careful detailed work extending over more than two years, that the effects of commercial pasteurisation on the food value of milk were negligible.

A *Statistics* section established in 1949 gives valuable assistance to departments, both in the planning of investigations and in the evaluation of the experimental data obtained. It also conducts research on statistical method.

The *Isotopes* section, formerly a part of the Physiology department, was given separate identity in 1953 in view of the importance, in an increasing proportion of the Institute's research, of techniques in which radioactive tracers and heavy isotopes are being used.

A small *experimental dairy* is concerned with the improvement of quality in butter and cheese and other dairy products, and has facilities for making these products under carefully controlled conditions.

In close association with the Institute is the Reading Cattle Breeding Centre of the Ministry of Agriculture and Fisheries. Joint research, both fundamental and technical, on artificial insemination is in progress between this Centre and the Institute.

The Institute is closely related to the University of Reading. The established members of its staff are members (several of them tutors), and the Director a Professor, of the University, whilst the Chancellor, the Vice-Chancellor and four other representatives of the University Council sit on the Governing Board of the Institute. The Institute submits its research programme annually to the Agricultural Research Council for scrutiny and approval, and receives the largest part of its income by a block grant from public funds administered through the Ministry of Agriculture and Fisheries after such approval has been given. In 1953, the cost of maintaining the Institute's work represented approximately 0·06 per cent. of the receipts of the industry for milk produced during that year.

Publications (*see* article on Research, Dairy, p. 921).

The Institute also publishes an Annual Report in which is given a brief account of the various research projects under investigation or recently published. Occasionally, monographs or special research bulletins, of a size which would be unacceptable by a scientific or technological journal, are published by the Institute. Persons interested in dairy research or dairy science can become " members ", " fellows " or " patrons " of the Institute. These individuals receive Institute publications either free of charge or at a reduced fee.

Staff. The staff consisted in 1953 of just over 90 scientific (graduate) workers and some 90 laboratory assistants and maintenance staff. The Director is Professor H. D. Kay, C.B.E., F.R.S., the Deputy Director is Dr. A. T. R. Mattick, and the Secretary H. F. Burgess, M.B.E. (1954).

NATIONAL MILK TESTING [AND ADVISORY] SCHEME. The prime object of this Scheme was to prevent souring and the first step to organise a standard method of testing all incoming milk on the creamery platform in order to weed out milk that fell below a certain standard. It is well established that the souring of large bulks of milk is due to the incorporation of a proportion of milk of very high bacterial count, *i.e.* potentially soured milk. The second step was the organisation of a complete grading scheme to ensure the bacteriological testing of every producer's milk at regular, *e.g.* fortnightly, intervals, and so to permit the classification of all producers into good, bad, and indifferent grades, which could ultimately form the basis for a system of quality payment.

The Standard Platform (" Rejection ") Test. Up to 1942 there was uniformity neither of tests nor of technique for any given test; each creamery chose its own standards. Barkworth, Davis, Edgell, Rowlands and Watson (1943, *DI*, **8**, 215), showed that, taking the methylene blue test as a criterion, the 10 min. resazurin test was the most reliable of all the recognised platform tests, and the rapid resazurin test was adopted by the Ministry of Agriculture as the official platform rejection test.

The change over from the titratable acidity test, which was a long-established tradition of the dairy industry, to a new and comparatively unknown test naturally surprised many people, some of whom were reluctant to drop the old test. There is little doubt, however, that titratable acidities as a measure of the hygienic quality of producers' milks are in theory unsound and in practice unreliable. Tests on milks selected at random show that there is practically no correlation between titratable acidity and the results of the methylene blue tests Obviously soured milks naturally give a good correlation. The so-called acidity is a measure of phosphate and protein, and such factors as mastitis, watering, and poor feeding have the effect of lowering the acidity and so making the milk appear better by the test. In fact, by a judicious use of these three factors, any producer could get his milk to pass the ordinary acidity test. Conversely, milk high in solids-not-fat and free from mastitis and not watered would fail an acidity test much more easily than a thin, mastitis-ridden milk containing added water. The resazurin test is free from these disadvantages; it is unaffected by the solids-not-fat content and watering, and is sensitive to the cells which are more numerous in mastitis than in normal milk. A " mastitis milk " is therefore marked up in the acidity test and marked down by the resazurin test. Although only put forward originally as a quick sorting-out test, the rapid resazurin test correlates quite well with the ordinary long-time methylene blue test.

Choice of Standards. The bacteriologists concerned were asked to select standards (*a*) for *salvage*, and (*b*) for *rejected milk*. *Salvage milk* is defined as milk too poor to be mixed in with bulk destined for the liquid market, but good enough to be utilised on the spot, *e.g.* for butter or cheese, or for pasteurising. *Rejected milk* is milk of such poor quality that it must be returned to the farmer. Under normal conditions salvage milk would be returned, but in wartime the need for utilising all the milk possible justifies an attempt to absorb milk of this quality. This salvage category has now been abandoned.

The selection of disc 3½ or lower in the 10 min. test, corresponding to a methylene blue reduction time of a ½ hr. or less, was based on the experience of the trade. It is generally agreed that milk can be handled in London if the methylene blue reduction time is not less than a ½ hr. To achieve this, refrigerated bulk milk should be sent off with a methylene blue reduction time of not less than 1 hr. It is obvious, therefore, that the ½ hr. standard is a reasonable one, and that if all milks failing this standard are withheld and utilised locally, there should be little risk of bulk milks being returned in a sour condition.

Salvage can only be applied to milk of a certain class, however, and it is commercially accepted that when milk clots on boiling (titratable acidity about 0·24 per cent.) the life of the milk is at an end.

It may be mentioned that the rejection standard adopted (disc ½ or 0 in 10 min.) is more severe than the " clot-on-boiling " test. Usually about half the samples rejected at disc ½ or 0 clot-on-boiling.

The Resazurin Test. Consideration of equipment in wartime automatically ruled out the plate-count, coli, and direct microscopic count as possible tests, leaving only the methylene blue and resazurin (1 hr. or a standard method) tests for consideration. The Milk Testing Panel ultimately advised a standard resazurin test, the time of incubation being varied from 2 hr. when the mean atmospheric temperature was 40° F. or less, to 15 min. when the mean atmospheric temperature was over 65° F. (later 60° F.). This arrangement was intended to level out the proportion of failures in summer and winter. Dye reduction tests are well known to be sensitive to temperature, but it is not possible to work out theoretically or experimentally an accurate correction for this factor.

The reasons which influenced the committee on the choice of this test for routine grading are set out below:

Probably no other test can be compared with the resazurin test for adaptability. It can be used as a rapid test on the platform, for routine grading, in combination with the rennet test, for sterility of churns, and, doubtless, further modifications will be devised. Both the end-point (disc reading) and the time of incubation can be varied at will, and this fact endows the test with enormous flexibility.

Only one reading, *e.g.* after 1 hr., is required, compared with six to twelve readings in the methylene blue test, requiring up to 6 hr.

The 1 hr. test can be carried out at 3 p.m. or 4 p.m. on the day of sampling for P.M. and mixed milks, thus avoiding refrigeration overnight, which has a variable effect and generally allows bad milks to deteriorate.

A milk rich in weakly reducing organisms usually affects resazurin, but may fail to reduce methylene blue for many hours.

A high count of cells, whether due to mastitis, late lactation, or colostrum, is disadvantageous in milk for many reasons. Resazurin, but not methylene blue, is affected by large numbers of cells in aged milk.

In a short-time test the result is more likely to bear a relation to the initial flora than in a longer test, especially in cold weather.

Any contamination will naturally influence a short test less than a long test.

Regarding its use as a " Methylene Blue Test ", if desired, the test can be prolonged to complete reduction of the dye, so that it becomes for all practical purposes a methylene blue test, if taken to disc ½ (mottled pink-white).

The advantage of standardising as many tests as possible fundamentally on one technique such as the resazurin test will be obvious.

A matter of great interest is the relation between the resazurin (1 hr.) test and the methylene blue test, and it has been shown that the correlation between the two tests is reasonably good. The known variability of the bacterial quality of a producer's milk implies that systematic testing is the essential feature of any testing and improvement scheme. Any one of the four recognised tests (plate-count and coli, microscopic count, methylene blue, and resazurin) is adequate for the purpose; the logical conclusion, therefore, is to choose the simplest, cheapest, and quickest.

Plate count, microscopic count, and the dye reduction tests measure rather different things in milk. When discussing bacteriological tests for milk, it is important to remember that we have no universally acceptable criterion such as we have for chemical tests for fat, etc. Broadly speaking, plate count and microscopic count measure numbers, and the dye tests measure activity. Since the latter is more closely related to potential souring, the choice of a dye test is quite logical.

We may summarise the matter by saying that with the resazurin test we measure a multiple complex of the bacteriological and hygienic quality of the milk. This complex has three components weighted in the following order: (1) reducing (usually also souring) bacteria; (2) other bacteria; (3) cells resulting from mastitis, etc.

The first component is easily the most, and the third easily the least, important.

The scheme has been in existence since 1942 and now that the original cause of its inception no longer exists, the time is appropriate for a summing up of what it has achieved. The cardinal points which may be emphasised are:

(i) Approximately 95 per cent. of the milk supplies and 90 per cent. of producers' milks are now tested for hygienic quality (p. 64) every fortnight or month.

(ii) Summarised results of these tests may not show any incontestable improvement because temperatures are the predominating factor in any one year, but at least it can reasonably be claimed that the hygienic quality of the nation's milk supply has been maintained.

(iii) The greatest weakness of the scheme has been the advisory and " follow-up " side, partly because of the lack of adequately-trained and experienced farm advisers, and partly because of the absence of any quality payment scheme.

(iv) The sterility tests on churns have shown a great improvement; this is perhaps the most tangible beneficial result of the scheme.

(v) The entire industry is now using standardised tests, techniques, and standards for grading. This is of itself a great advance and producers now have less suspicion of victimisation or unfair criticism.

As the result of discussions with the industry, the scheme was handed over to a Joint Quality Control Committee representing the producers and the buyers in 1949. A Technical sub-committee has been appointed to consider all the technical aspects of the scheme.

See Bacteriological grading of milk ; Churns, cleaning of ; Clean milk production ; Farm advisory work ; Laboratories, organisation of ; Platform testing ; Quality payment ; Resazurin tests ; Routine tests ; Testing of milk supplies.

NEUFCHATEL. *See* Cheese, p. 197.

NEUTRALISATION OF LACTIC ACID IN CREAM. The titratable acidity (L per cent. of lactic acid) and the fat content (F per cent.) of the cream are determined. (The *serum acidity* is then $\frac{100\,L}{100-F}$ per cent.) To reduce the serum acidity of 1000 lb. of cream of F per cent. fat content by 0·1 per cent. requires 0·017 (100 — F) oz. of *sodium bicarbonate*, or 0·0075 (100 — F) oz. of pure *calcium hydroxide* ($Ca(OH)_2$). *See* Acidity of milk ; Butter ; Cream.

NEW ZEALAND.

Refs.: Riddet (1953), *JSDT*, **6**, 212; Campbell and Dolby (1953), *DSA*, **15**, 669; Riddet (1954), *JSDT*, **7**, 14; Taylor (1949), *JSDT*, **2**, 187; White (1949), *IDC* **4**, 636; Twomey (1951), *DI*, **16**, 1163; (1952), *DI*, **17**, 44.

NICHOLL'S EQUATION FOR FAT IN CHEESE. $W = mF + \frac{100-S}{100}\,.\,K$

W = percentage of water ; F = percentage of fat ; S = percentage of salt ; K (constant) = 93·0 for hard pressed cheese and 93·3 for cream cheese ; m = factor for fat in original milk or cream.

Ref.: Nicholls (1941), *A*, **66**, 265.

NICKEL. Nickel alloys and nickel-plated metals are still used in the dairy industry, but are steadily being replaced by stainless steel where fabrication is an economic proposition. It has been claimed that nickel is the only metal on which a satisfactory protective film is formed with milk, especially if the milk is warm and saturated with air. Nickel is anodic to copper and stainless steel and cathodic to aluminium, tin-plated copper and lead tin solder, so that the latter group corrodes when used with nickel, while nickel tends to corrode with the former. Nickel-chromium alloys are highly resistant not only to milk but also to brine, detergents, and hypochlorites, and it is the latter which are the commonest cause of corrosion in the dairy industry especially at low *p*H values (below 7). The copper-nickel alloys should be avoided as not only can dissolved copper be the cause of oxidised taint in cold milk (p. 475) but these alloys are not very corrosion resistant if the milk undergoes scouring. *See* Metals.

Ref.: Bradbury (1947), *JSDT*, **1**, 23.

NILE BLUE SULPHATE. A dye used in media for detecting lipolysis (p. 615) by micro-organisms. *See* Media ; Enzymes (lipase).

Refs.: Levine and Schoenlein ; Richards (1946), *SAB*, p. 104.

NISIN. *See* Antibiotics.

NITRATES. (i) **In Milk.** (*a*) *As a preservative.* Nitrate is almost negligible as a preservative but it has been used as a deodoriser. (*b*) *As a means of detecting added water.* The fact that most naturally occurring water contains nitrate is the basis of tests for the detection of added water by determining the amount of nitrate in the suspected milk. The method is, however, much inferior to the freezing-point test because (i) waters vary in their nitrate content; (ii) tests for nitrate are not specific; (iii) this method is not as sensitive or accurate as the freezing-point test (p. 485).

(ii) **In Butter.** The use of nitrates or any other preservative for butter is illegal but nitrates were formerly used on occasions.

(iii) **In Cheese.** Nitrates have been extensively used on the Continent and in Canada for the prevention of " blowing " or gas holes in cheese (p. 180) caused by the growth of coli-aerogenes bacteria. The accepted explanation is that in the presence of the oxidising nitrate, the hydrogen that would be liberated by bacterial fermentation is oxidised to water. In Holland for example, 1 g. of saltpetre may be added to 1 gal. of milk.

This method has been abandoned in some countries because of the danger of colour defects arising from the " coupling " of certain amino acids such as tyrosine with the nitrite which is formed by the reduction of the nitrate. Nitrate does not prevent gas formation by the propionic or butyric acid bacteria.

NITRITES. These salts are formed by the reduction of nitrates in dairy products by bacteria.

NITRO-CASEIN. A yellow compound (or mixture) obtained by the action of nitric acid on casein.

NITROGEN. For Gas Packing of Milk Powders. Spray-dried powders (full-cream) are very susceptible to oxidative changes due to the fine state of division of the fat and the low temperature of heating. This taint development can be deferred for a long period by packing the powder in tins which are first exhausted and then filled with nitrogen, an inert gas which does not permit oxidation. *See* Auto-oxidation ; Milk powder.

NITROGEN FACTOR. The protein (p. 859) content of milk and milk products and indeed of all foodstuffs is commonly determined by estimating the nitrogen content by the Kjeldahl or other method and then multiplying this value by a factor which is the inverse ratio of the nitrogen content of the protein. For most proteins a value of 6·25 is used but for casein 6·38 should be used as the nitrogen content is 15·68 per cent. and for albumin 6·48 (15·43 per cent. nitrogen).

NOISE. One of the worst drawbacks to work in a dairy is the noise which arises from a number of causes. In order of importance they are : (i) steam jets in churn washers ; (ii) clanking of bottles in bottle-washing machines and on conveyors ; (iii) handling of churns and loosening of lids ; (iv) handling of crates.

It would be of great benefit to dairy operatives if these noises could be eliminated or reduced. Possible remedies would be : (i) elimination of high-pressure steam jets, using only boiling water and possibly hot air blasts. The use of a bactericidal detergent or hypochlorite in place of steam for killing effect on bacteria ; (ii) improved design in bottle-washing machines. Many conveyors move much faster than necessary in dairies ; (iii) mechanical devices for tipping churns ; improved design for churn lids and necks to minimise jamming ; aluminium churns ; (iv) mechanical devices for emptying and filling crates.

NON-DESTRUCTIVE METHODS OF TESTING.

Refs.: Armour (1953), *LP*, **2,** 175, 236, 306, 368, 428.

NON-SPECIFIC MASTITIS. An abnormal condition in the udder or milk in the absence of detectable mastitis-causing organisms. *See* Abnormal milk ; Mastitis.

Ref.: van Rensburg (1947), *Ond. J. Vet. Sci.*, **22,** 91.

NORMALISING. This term is applied to a heat treatment necessary to restore the fat globules and other constituents of milk to a standardised or normal condition. Usually the milk is heated to 140° F. for 10 or 15 min.

NORWAY.

Refs.: Mann (1953), *Agric.*, **60,** 221; Benterud (1949) *IDC*, **4,** 646; Grindaker, 749; Mork (1941), *Milk Trade and Dairy Industry in Norway* (in Norwegian), Oslo.

NUTRITIVE RATIO. This ratio gives a guide to the value of a ration for growth and milk production as against its value for energy or fat production.

The ratio is given by the expression

$$\frac{\%\text{ digestible carbohydrates} + \%\text{ digestible fibre} + (\%\text{ digestible fat} \times 2{\cdot}3)}{\%\text{ digestible protein}}$$

A value of 4 or 5 is regarded as a narrow one suitable for growing stock or milking cows. A value of 7 or 8 is a wide ratio suitable for older fattening animals.

The ratio is simply an expression of the energy value of a ration against its body-building power. Fat has 2·3 times the energy value of starchy matter. *See* Feeding.

NUTRITIVE VALUE OF DAIRY PRODUCTS. Milk is generally acknowledged as the most nearly perfect single foodstuff, but its great importance lies probably in the ability to improve a mixed diet. Variations in composition attributable to season, breed of cow, her feeding, management and stage of lactation, though important for separate constituents, do not seriously affect its general value. Table NV 1 gives the average composition of 100 g. of summer milk.

TABLE NV 1

AVERAGE COMPOSITION OF 100 g. SUMMER MILK

(Kon (1947); Kon and Porter (1947-48); Kon and Henry (1949); Ford *et al.* (1953))

Major constituents		*Minerals*		*Vitamins**	
Water	87·6 g.	Calcium	0·12 g.	A Carotene	150 i.u.
Total solids	12·4 g.	Phosphorus	0·10 g.	B_1	35 μg.
Protein	3·3 g.	Magnesium	0·01 g.	Riboflavin	150 μg.
Fat	3·6 g.	Iron	0·03 mg.	Nicotinic acid	90 μg.
Carbohydrate	4·7 g.			B_6	70 μg.
Calories	66			Biotin	2-8 μg.
				Pantothenic acid	350 μg.
				Choline	14 mg.
				"Folic acid"	Traces
				p-aminobenzoic acid	4-15 μg.
				Inositol	18 mg.
				B_{12}	0·3 μg.
				C	2 mg.
				D	4 i.u.
				E	100 μg.
				K	Traces

* These are rounded-off figures.

The importance of milk in the diet is due mainly to its contribution of high quality animal protein, its exceptional richness in calcium, and its generous supply of preformed vitamin A and of riboflavin and other members of the vitamin B_2 complex.

TABLE NV II

RECOMMENDED ALLOWANCES OF CERTAIN NUTRIENTS

(From British Medical Association (1950), *Report of the Committee on Nutrition*)

Requirement class		Calories	Protein (g.)	Iron (mg.)	Calcium (g.)	Vitamin A and carotene (i.u.)	Vitamin D (i.u.)	Vitamin B_1 (mg.)	Nicotinic acid (mg.)	Riboflavin (mg.)	Vitamin C (mg.)
Children, both sexes:											
0-1 years		1000	37	6·5	1·0	3000	800	0·4	4	0·6	10
2-6 years		1500	56	7·5	1·0	3000	400	0·6	6	0·9	15
7-10 years		2000	74	10·5	1·0	3000	400	0·8	8	1·2	20
Males:											
11-14 years		2750	102	13·5	1·3	3000	400	1·1	11	1·6	30
15-19 years		3500	130	15·0	1·4	5000	400	1·4	14	2·1	30
20 + years.	No work, almost basal (*e.g.* lying in bed)	1750	51	12·0	0·8	5000		0·7	7	1·0	20
	Sedentary work (30 Cals./hr.) and little travelling (65 Cals.)	2250	66	12·0	0·8	5000		0·9	9	1·4	20
	Light work (70 Cals./hr.) and travelling (130 Cals.)	2750	80	12·0	0·8	5000		1·1	11	1·6	20
	Medium work (100 Cals./hr.) and travelling (130 Cals.)	3000	87	12·0	0·8	5000		1·2	12	1·8	20
	Heavy work (200 Cals./hr.) and travelling (130 Cals.)	3500	102	12·0	0·8	5000		1·4	14	2·1	20
	Very heavy work (300 Cals./hr.) and travelling (130 Cals.)	4250	124	12·0	0·8	5000		1·7	17	2·6	20
	Extremely heavy work (450 Cals./hr.) and travelling (130 Cals.)	5000	146	12·0	0·8	5000		2·0	20	3·0	20
Females:											
11-14 years		2750	102	13·5	1·2	3000	400	1·1	11	1·6	30
15-19 years		2500	93	15·0	1·1	5000	400	1·0	10	1·5	30
20 + years.	No work, almost basal (*e.g.* lying in bed)	1500	44	12·0	0·8	5000		0·6	6	0·9	20
	Sedentary work (30 Cals./hr.) and little travelling (50 Cals.)	2000	58	12·0	0·8	5000		0·8	8	1·2	20
	Light work (70 Cals./hr.) and travelling (100 Cals.)	2250	66	12·0	0·8	5000		0·9	9	1·4	20
	Medium work (100 Cals./hr.) and travelling (100 Cals.)	2500	73	12·0	0·8	5000		1·0	10	1·5	20
	Heavy work (200 Cals./hr.) and travelling (100 Cals.)	3000	87	12·0	0·8	5000		1·2	12	1·8	20
	Very heavy work (300 Cals./hr.) and travelling (100 Cals.)	3750	109	12·0	0·8	5000		1·5	15	2·2	20
Pregnancy:											
First half		2500	93	12·0	0·8	6000	400	1·0	10	1·5	40
Second half		2750	102	15·0	1·5	6000	600	1·1	11	1·6	40
Lactation		3000	111	15·0	2·0	8000	800	1·4	14	2·1	50

NUTRITIVE VALUE OF DAIRY PRODUCTS

The nutritive contribution of milk may be assessed to a certain extent by expressing it in terms of dietary requirements. Table NV II gives the daily dietary allowances of the more important nutrients as recommended by the Committee of Nutrition of the British Medical Association (1950). Table NV III shows to what extent 1 pint of milk allows a child and an adult to meet these requirements. It will be seen that it supplies about seven-eighths of the calcium, just over one-fifth of the protein, nearly one-half of the riboflavin and just under one-fifth each of the vitamin A and vitamin B_1 recommended for an adult man doing medium work. The contribution to the needs of children aged 2 to 6 years is not only larger but more uniform, indicating the special value of milk for the young.

TABLE NV III

Approximate Percentage Contribution of 1 Pint Summer Milk to the Recommended Dietary Allowance (Table NV II) for a Child and for a Man doing Medium Work

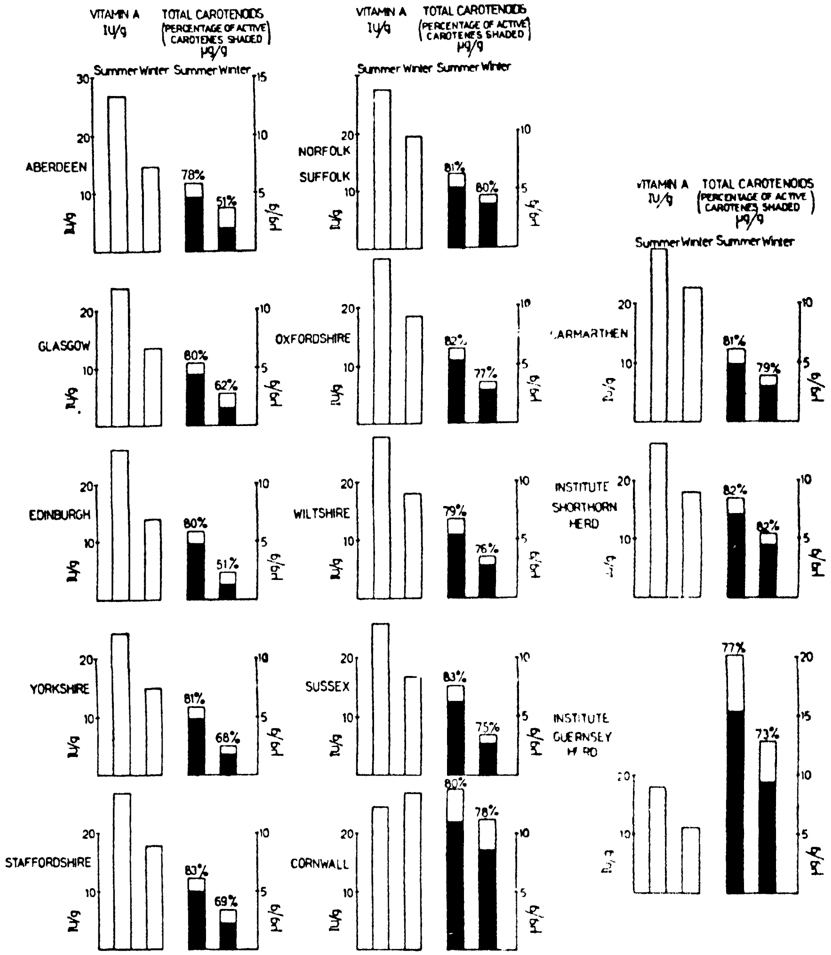
Nutrient	*Child* 2-6 *years*	*Man medium work*
Calories (half from fat) .	25	13
Protein	34	22
Iron	2	1
Calcium . . .	69	86
Vitamin A (in fat) . .	29	17
Vitamin D (in fat) . .	3	—
Vitamin B_1 . . .	33	17
Nicotinic acid . .	9	4
Riboflavin . . .	95	48
Vitamin C . . .	13	10

The proteins of milk and cheese are particularly valuable on account of the supplementary relationships between them and other proteins in a mixed diet. A very striking effect is obtained, for example, with such a staple food combination as bread and cheese; the low nutritive value of bread protein can be raised to the high value of that of cheese if half the bread protein is replaced by cheese protein (Henry and Kon, 1946).

The chief importance of milk fat lies in its contribution of calories and the fat-soluble vitamins. Nearly half the calories in milk are derived from it, and it is finely dispersed and easily assimilable. As a result of experiments on rats, claims have been put forward for the existence of some unknown nutritional factor in butterfat (particularly in summer), making it superior on that score to vegetable fats. The conflicting evidence has been summarised by Kon and Henry (1949).

Milk fat is a more important source of vitamin A than of vitamin D, the content of both is subject to seasonal variations. The very large fluctuations in vitamin A are mostly connected with the carotene content of the fodder of the cow. The carotene of grass, hay, silage, cabbage or kale appears in the milk partly as vitamin A and partly in its original form. In late spring, summer and autumn when grass is abundant or kale is fed, the vitamin A activity of milk is at its best. It usually declines steadily from November to reach its lowest point in March or April just before cows go out to grass again. A higher level may be maintained in winter by feeding silage of high carotene content. A very marked increase in vitamin A can be obtained by feeding high potency oils or concentrates, *e.g.* shark-liver oil (Blaxter *et al.*, 1946), but cod-liver oil cannot be used for this purpose as it depresses the fat content of milk (Channon *et al.*, 1924;

Drummond *et al.*, 1924). Fig. NV 1 shows the variations in the vitamin A activity of samples of milk obtained from different parts of the country (Thompson *et al.*, 1949). Similar work was done on a large scale in the United States of America (U.S. Dept. Agric., 1947).

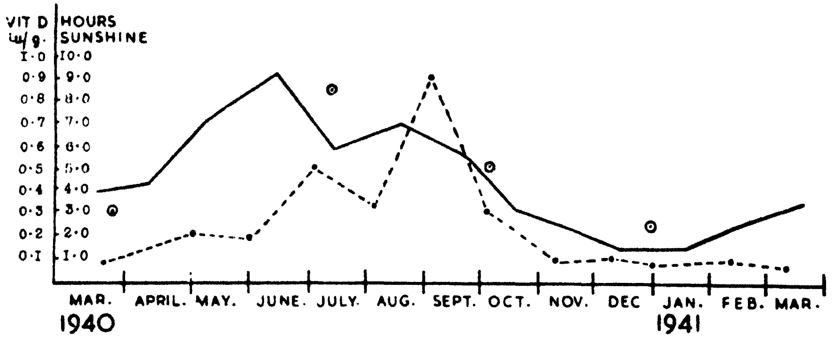


[*By courtesy of N.I.R.D.*

FIG. NV 1.—*Seasonal Fluctuation in the Vitamin A, Carotenoids and active Carotenes in Milk Fat in Great Britain* (1943-44).

Winter milk contains about 0·1 i.u. vitamin D per g. fat and summer milk up to 2 i.u. per g. fat. During the stall-feeding period vitamin D is mainly derived from hay. In the summer the sun contributes all and the pasture none of the increase in the vitamin D potency (Campion *et al.*, 1937). Fig. NV 2 shows the seasonal variation in the vitamin D content of the milk of a herd of Shorthorns. The vitamin D content of milk is much too low to be of practical value for children. It may, however, be increased artificially to useful levels, usually about 140 U.S.P.

units per quart (American), and it is generally agreed that such enriched milk is most valuable in the prophylaxis of rickets. There are three practical methods of enrichment: direct irradiation of the milk with ultra-violet light, addition of vitamin D concentrates, and the feeding to cows of irradiated yeast. All three methods were used on a large scale in the United States, but since the last war direct addition of suitable concentrates has been the method of choice. The irradiation of milk was increasingly applied in Germany before the war, and the process is now being further expanded. Vitamin D milk has not been produced to any great extent in this country, though since the war the Ministry of Food has been distributing for infant feeding dried half-cream and full-cream milk containing 280 i.u. per oz. of vitamin D (Kon and Henry, 1949).



[*By courtesy of* The Biochemical Journal.

FIG. NV 2.—*The Seasonal Variation of the Vitamin D Content of English Butterfat in Relation to change in Sunshine.* ——— *Average Daily Hours of Sunshine (Reading).* ------ *I.U. Vitamin D/g. Fat Measure on the Non-saponifiable Residue of Butterfat.* ⊙ *I.U. Vitamin D/g. Measured on Butterfat.*

The vitamin B_1 content of milk is independent of that of the feed, and in bulk milk remains more or less constant throughout the year. The cow synthesises vitamin B_1, possibly in the rumen with the help of bacteria.

Milk is an important source of riboflavin, and in the United States, dairy products supply nearly one-half of the total daily intake (Cheldelin and Williams, 1943). The riboflavin content of milk varies but little throughout the year in a way not directly related to feed of cow or season. Riboflavin is sensitive to light and serious losses may occur as a result of undue exposure of the milk to light (Kon and Henry, 1949).

Milk contains measurable amounts of most of the other members of the vitamin B_2 complex, and some of them are known to be synthesised in the rumen. As man's needs for most of these factors have not yet been assessed, it is not possible to say how important milk is as a source of these nutrients, but it has been estimated that its contribution of pantothenic acid is appreciable. The nicotinic acid content of milk is low and the amount contributed by it to the diet is negligible. Nevertheless, the pellagra-preventive action of milk and milk products is well known, and it has been suggested that milk has a stimulating effect on the synthesis of nicotinic acid by the bacterial flora. It may also act by contributing the amino-acid, tryptophan, from which nicotinic acid is formed in the body.

Milk may supply a considerable proportion of the daily needs of man for vitamin C (Mawson and Kon, 1945), but variations in content are considerable. As it leaves the udder, milk contains 2 to 2·5 mg. vitamin C per 100 g. By the time it reaches the consumer, however, considerable losses may occur. This is largely due to the interesting phenomenon of induced photochemical oxidation of vitamin C by light. The vitamin itself is colourless, that is, it does not absorb visible light and cannot be affected by it; riboflavin, however, which is yellow, absorbs blue light and acts as a sensitiser. The effects of exposure to light are quite dramatic. Thus, a pint bottle of milk left on the doorstep in the usual way for half-an-hour and then placed in the larder loses, by the time it is consumed, fully half of the vitamin C originally delivered by the milkman. The destruction is in stages: under the action of light, vitamin C is transformed into dehydroascorbic acid; this, though still biologically active, is unstable and decomposes further, spontaneously, even in the dark, or under the action of heat. These losses may be prevented, or minimised, by avoiding exposure to light or by the removal of oxygen from the milk, as this element is needed for the action of light. Table NV IV shows the variations in the vitamin C content of milk as consumed in Reading and Fig. NV 3 the effect of light on this vitamin. Appreciable protection from light is afforded by cartons as compared with clear glass bottles; brown glass bottles would be even better.

TABLE NV IV

MEAN VALUES FOR THE VITAMIN C CONTENT OF MILK AS CONSUMED IN READING

(Mawson and Kon, 1945)

Serial No.	*Description of samples*	*No. of samples*	*Total vitamin C*			
			(mg. per 100 ml.)		*(mg. per pint)*	
			Mean value with its standard error		*Mean value with its standard error*	
1	Total	151*	0·99	± 0·043	5·6	± 0·24
2	August, 1943 . .	85*	0·89	± 0·057	5·0	± 0·32
3	January, 1944 . .	66	1·13	± 0·062	6·4	± 0·35
4	Raw milk . . .	71	1·34	± 0·055	7·6	± 0·31
5	Heated milk . .	75	0·69	± 0·043	3·9	± 0·24
6	Raw milk: August .	38	1·28	± 0·080	7·2	± 0·45
7	Raw milk: January .	33	1·42	± 0·073	8·0	± 0·41
8	Heated milk: August .	42	0·57	± 0·014	3·2	± 0·08
9	Heated milk: January .	33	0·83	± 0·072	4·7	± 0·41
10	No. 6 samples that did not stand on doorstep .	27	1·36	± 0·086	7·7	± 0·49
11	No. 6 samples that stood on doorstep 15 min. or more . . .	11	1·10	± 0·165	6·2	± 0·95
12	No. 6 samples consumed on day of delivery .	16	1·46	± 0·109	8·3	± 0·62
13	No. 6 samples consumed on day after delivery .	22	1·15	± 0·106	6·5	± 0·60

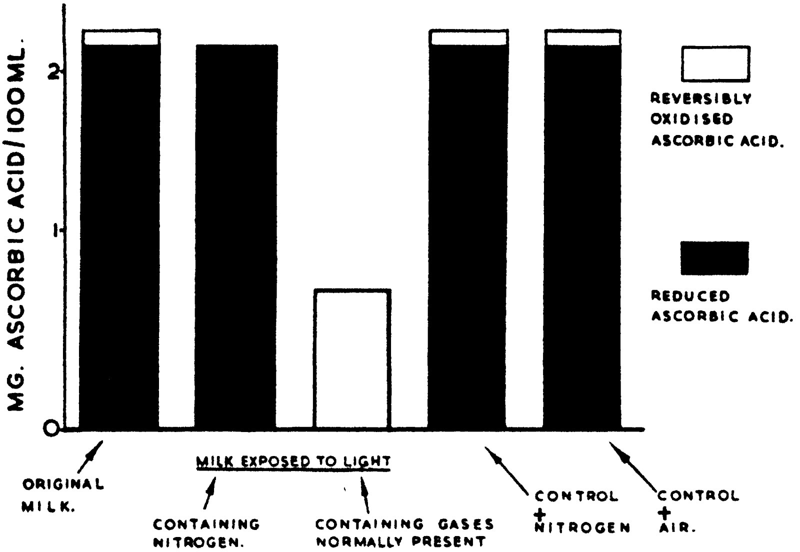
* It was not known whether 5 of these samples were raw or treated by heat.

Raw milk is subject to bacterial contamination, and to ensure safety of the liquid milk about 90 per cent. of the commercial supply in this country is pasteurised. Other methods of preservation are sterilisation (p. 990), evaporation, condensing (p. 277), and drying (p. 716).

Table NV V shows the effect of the various heat treatments on the nutritive value of milk.

In general, heating for a short period at a high temperature is less injurious than prolonged heating at a lower temperature.

Pasteurisation causes a loss of about 10 per cent. of the heat-labile vitamin B_1 and of some 20 per cent. of vitamin C. It has been shown in laboratory experiments that in milk as it comes from the udder and not exposed to light vitamin C withstands pasteurisation without loss (Kon and Watson, 1936). Contamination with copper during pasteurisation leads to serious losses of vitamin C. Vitamins A and D, riboflavin, vitamin B_6, pantothenic acid, nicotinic acid and biotin are not normally affected by pasteurisation (Kon and Henry, 1949); neither is the nutritive value of the proteins (Henry, Kon and Watson, 1937). High-temperature, short-time (H.T.-S.T.) pasteurisation is even less injurious; loss of vitamin C, for example, is less than 5 per cent.



[*By courtesy of* The Biochemical Journal.

FIG. NV 3.—*Effect of Light on the Ascorbic Acid of Milk in the Presence of Oxygen or of an Inert Gas. Two Hours' Exposure to Afternoon February Sunshine.*

The heat treatment of sterilised milk is more drastic, and there is greater destruction of vitamins B_1 and C. The nutritive value of the proteins also is slightly impaired. As far as is known other factors are not affected (Kon and Henry, 1938).

Losses in unsweetened evaporated milk are similar to those found for sterilised milk; but in sweetened condensed milk, because of milder heat treatment, the changes are only of the same order as in pasteurised milk. Spray-drying and careful roller-drying of milk also cause losses of the order observed after pasteurisation. The proteins are probably unharmed, as values comparable with those for raw or freeze-dried milk may be obtained for highest quality dried milk, though with some commercial samples a certain deterioration is evident.

Loss of nutrients during drying is thus slight. Further losses may occur, however, if storage conditions are not satisfactory.

Full-cream dried milks deteriorate rapidly if stored in the presence of air because of oxidative changes in the fat, but they can be kept for a long time hermetically sealed in an atmosphere of inert gas such as nitrogen or carbon dioxide. If, however, the temperature to which milk is preheated before drying is raised to 190° F. instead of the usual 165° F., powders so produced are much more resistant to oxidation when exposed to air because of the formation of

TABLE NV V

COMPOSITION OF DIFFERENT FORMS OF MILK [1]

(Kon (1941) revised)

Form of milk	*Calories per 100 g.*	*Grams per 100 g.*					*Vitamin A activity* [2]		*Vitamin D* [2]		*Vitamin B_1*		*Riboflavin*		*Vitamin C* [3]	
		Water	*Protein (N × 6.38)*	*Fat*	*Carbohydrate*	*Calcium*	*i.u per 100 g.*	*Loss in manufacture*	*i.u. per 100 g.*	*Loss in manufacture*	*mg. per 100 g.*	*Loss in manufacture*	*mg. per 100 g.*	*Loss in manufacture*	*mg. per 100 g.*	*Loss in manufacture*
												%				%
Raw	66	87·6	3·3	3·6	4·7	0·120	70-200	—	0·5-3·0	—	0·035	—	0·15	—	0-2·5	—
Holder-pasteurised	66	87·6	3·3	3·6	4·7	0·120	70-200	None	0·5-3·0	None	0·033	10	0·15	None	0-2·0	20
Sterilised	66	87·6	3·3	3·6	4·7	0·120	70-200	None	0·5-3·0	None	0·024	30	0·15	None	0-1·2	50
Spray-dried whole	512	3·0	25·0	27·5	37·5	0·910	550-1600	None	3·9-23	None	0·255	10	1·2	None	0-16	20
Roller-dried whole	512	3·0	25·0	27·5	37·5	0·910	550-1600	None	3·9-23	None	0·240	15	1·2	None	0-13	30
Dried skim	357	4·0	36·0	0·5	50·0	1·250	Trace	Most	None	All	0·345	10	1·8	None	0-20	30
Condensed whole	169	68·5	8·4	9·2	12·0	0·300	180-500	None	1·3-7·6	None	0·054	40	0·38	None	0-2·5	60
Condensed whole, sweetened	344	25·0	8·8	9·5	53·5	0·325	190-530	None	1·4-8·1	None	0·087	10	0·41	None	0-5·7	15

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[1] The composition varies from sample to sample; the figures given in the table may be taken as representative.

[2] Varies according to season.

[3] Varies according to the handling of the liquid milk.

sulphydryl compounds which act as anti-oxidants, and of the more complete destruction of oxidising enzymes. Table NV VI shows the effect of storage on the vitamin content of samples of whole dried milk prepared and kept under different conditions. The higher temperature of preheating is no more deleterious to the labile vitamins or to the proteins than the lower one, the stability on storage in air- or gas-pack of carotenoids and of vitamin C, and to a lesser extent of vitamin A, is enhanced, and the keeping quality of the gas-packed milk is remarkable (Mattick *et al.*, 1945; Henry and Kon, 1947).

TABLE NV VI

EFFECT OF STORAGE ON THE VITAMIN CONTENT OF SAMPLES OF WHOLE DRIED MILK PREPARED IN NOVEMBER, 1942, AND KEPT UNDER DIFFERENT CONDITIONS

(Mattick *et al.*, 1945)

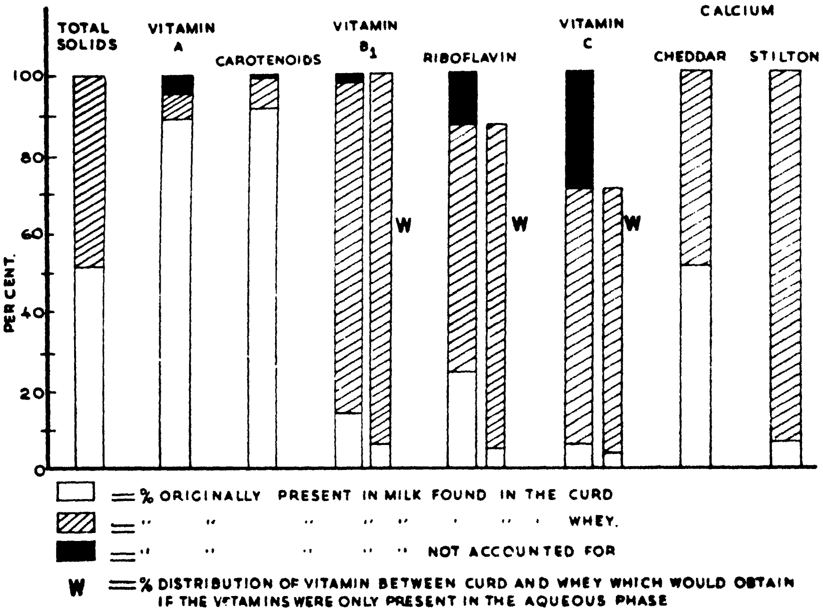
Preheating temperature °F.	*Date of test*	*Type of packing*	*Total ascorbic acid µg./g. powder*	*Carotenoids µg./g. powder*	*Vitamin A i.u./g. powder*
165	Nov. 1942	Air	110	1·71	6·55
	Feb. 1943		94	1·53	6·40
	Aug. 1943		77	1·09	5·28
	Nov. 1942	Gas	120	1·79	7·00
	Feb. 1943		108	1·62	6·65
	Aug. 1943		99	1·61	5·84
190	Nov. 1942	Air	100	1·72	6·60
	Feb. 1943		101	1·62	6·85
	Aug. 1943		91	1·46	5·66
	Nov. 1942	Gas	100	1·82	7·15
	Feb. 1943		113	1·62	7·00
	Aug. 1943		102	1·64	6·13

Cream has proverbially been considered as the most valuable part of milk, and milk from which the fat has been removed has borne a stigma of inferiority. In spite of improved knowledge of food values the prejudice against the use of dried skim milk persists. The absence of fat and of vitamin A makes it wholly unsuitable as a food for babies, and in this country it must be clearly labelled to this effect. All the other important constituents remain unimpaired and, for that matter, are proportionately increased at the expense of the missing fat. The high content of animal protein, calcium and riboflavin makes dried skim milk a most valuable addition to the diet. It is much less prone than the full-cream product to oxidative changes and can be stored in the presence of air for long periods of time without loss of nutritive value, providing its moisture content is below 3 per cent.

Higher moisture results, on storage, in a gradual loss of palatability, solubility and biological value of the proteins. These changes occur slowly at room temperature, but are accelerated at higher temperatures. They are more marked in air-pack than in gas-pack. The lowering of the biological value of the milk proteins is largely due to a decrease in the availability of the amino-acid, lysine, which gradually forms with lactose a compound resistant to enzymic hydrolysis. The differences between air- and gas-pack samples are undoubtedly related to oxidative changes; the difference in the biological value of the proteins is due to loss or inactivation in air-pack of the amino-acid, histidine (Henry *et al.*, 1948).

The manufacture of cheese from milk involves changes in composition much more drastic than those so far discussed. It may be said that roughly one-half of the total solids of milk passes into the cheese, the other being lost in the whey. Fortunately some of the more valuable nutrients are preferentially recovered in the cheese. Whey is at present largely a waste product, but a certain amount is used for animals. If properly dried when fresh it is also a valuable addition to food products used by man.

Fig. NV 4 shows the distribution of some milk nutrients between the curd and whey in Cheddar cheese. A large part of the fat, coagulable protein and about half of the mineral salts are retained in the curd, whereas the soluble protein, lactalbumin, the milk sugar, the remainder of the mineral salts and a large part of the water-soluble vitamins are drained off in the whey. An interesting point is that cheese retains much more riboflavin and appreciably more vitamin B_1 than would be expected on the basis of simple partition of water, indicating that these two factors are partly in combination with the coagulable solids of milk (Dearden *et al.*, 1945).



(*By courtesy of the* Journal of the Royal Society of Arts

FIG. NV 4.—*Per cent. Distribution of Solids and Vitamins of Milk Between the Curd and Whey of Cheddar Cheese.*

Table NV VII gives figures for the concentration of various factors in cheese of various types analysed in three laboratories. Many other values will be found in the review by Kon and Henry (1949). Only small variations occur in cheese of a given type, but large differences are observed between types. Thus the calcium and phosphorus in Stilton and in cream and cottage cheese are very much lower than in the hard varieties. Some vitamins of the B complex are affected by the method of ripening; this is particularly so with Limburger, Camembert, and Roquefort. There is evidence to show that synthesis of certain of these factors occurs during ripening.

TABLE NV VII

Composition of Different Types of Cheese

Type of cheese	Moisture %	Fat %	Calcium %	Phosphorus %	Vitamin A i.u./g. fat	Carotenoids μg./g. fat	Vitamin B_1 μg./100 g.	Riboflavin μg./100 g.	Nicotinic acid μg./100 g.	Pantothenic acid μg./100g.	Biotin μg./100 g.
					Dearden *et al.* (1945)						
Cheddar winter	30·6	36·6	0·75*	0·51*	14·5	2·0	53·0	306			
summer	32·9	35·6			23·4	8·2	57·0	330			
Cheshire winter	32·7	35·5	0·68*	0·47*	13·5	2·0	45·0	264			
summer	32·8	35·2			23·4	7·6	46·0	330			
Stilton winter	25·4	43·5	0·11*	0·27*	15·0	2·1	80·0	226			
summer	18·9	46·7			23·4	8·4	75·0	375			
					Irvine *et al.* (1945)						
Cream	50·3	39·1	0·084	0·086				291			
Cottage	79·5	2·6	0·085	0·146				283			
Brick	33·8	29·5	0·684	0·426				467			
Blue	30·7	28·8	0·389	0·265				607			
					Sullivan *et al.* (1943)						
Cream	50·4	39·9						200	60	140	1·2
Swiss (processed)	40·2	28·7						400	70	260	1·1
American ripe	36·8	33·1						410	30	180	1·7
green	33·6	34·6						590	100	130	—
Colby	35·2	35·3						510	70	210	1·6
Old English (processed)	40·1	30·7						570	30	310	2·5
Brick	41·6	31·0						420	110	280	2·8
Parmisello (dried grated product)	17·2	30·0						710	110	530	4·3
Velveeta	45·7	23·9						550	140	550	4·6
Chantelle	40·8	33·0						470	50	320	3·6
Limburger (processed)	53·9	24·3						350	140	580	3·6
Camembert	53·1	25·9						830	1600	850	5·6
Roquefort	37·9	33·3						450	1240	960	7·6

* E. C. V. Mattick (1938).

TABLE NV VIII

WEIGHTS OF DRIED WHOLE MILK, UNSWEETENED CONDENSED MILK, CHEESE OR BUTTER MANUFACTURED FROM 100 LB. LIQUID MILK. CONTENT OF MAJOR CONSTITUENTS EXPRESSED IN LB. AND IN PERCENTAGE UNITS

	Liquid milk		*Dried whole milk*		*Unsweetened condensed milk*		*Cheddar or hard cheese*		*Butter*	
	lb.	%	*lb.*	%	*lb.*	%	*lb.*	%	*lb.*	%
Weight of product . .	100		12·8		40·0		9·7		4·2	
Fat content . . .	3·6	3·6	3·6	28	3·6	9·0	3·2	33	3·4	81
Protein content . .	3·3	3·3	3·3	26	3·3	8·3	2·6	27	0·04	1
Carbohydrate content .	4·7	4·7	4·7	37	4·6	11·7	—	—		
Mineral content . .	0·8	0·8	0·8	6	0·8	2·0	0·5	5	0·08	2
Water content . . .	87·6	87·6	0·4	3	27·6	69·0	3·8	35	0·7	16

TABLE NV IX

Food Supplies per Head per Year Moving into Civilian Consumption in the United Kingdom

(Min. Food, 1949)

	Lb. per head per year										
	Pre-war	1940	1941	1942	1943	1944	1945	1946	1947	1948 (*provisional*)	1948-49 (*provisional*)
Dairy products (excluding butter) :											
Liquid milk	216·9	233·3	265·0	283·7	298·6	308·0	314·0	312·7	304·3	323·4	336·7
Cream, 40 per cent . . .	1·3	0·5	—	—	—	—	—	—	—	—	—
Cheese	8·8	8·2	8·3	14·0	11·5	10·3	9·7	10·0	9·3	8·3	8·4
Evaporated milk [1] . . .	2·4	1·2	3·6	3·0	1·7	1·6	1·8	4·3	3·8	2·5	2·5
Condensed milk [2] . . .	4·0	3·2	0·7	1·1	1·4	1·0	1·0	1·0	1·1	1·4	1·9
Condensed milk [3] . . .	5·9	3·6	1·2	1·1	1·8	1·6	1·5	1·4	1·2	1·1	1·6
Dried whole milk . . .	0·6	0·5	0·4	0·6	0·8	1·0	1·1	1·3	1·6	1·5	1·3
Dried skim milk	1·0	1·1	0·4	2·3	3·4	2·1	2·4	1·0	1·7	0·5	0·4
Total (as milk solids) . .	38·3	38·2	40·7	48·6	50·0	49·0	49·8	49·4	48·7	49·0	50·6
As percentage of pre-war . .	—	100	106	127	131	128	130	129	127	128	132

[1] Full cream unsweetened.

[2] Full cream sweetened.

[3] Machine skimmed sweetened.

Drying of milk and manufacture of cheese and butter convert the whole or part of milk into a form easily stored for considerable periods. Table NV VIII shows the retention of major milk constituents in these processes in terms of weight and percentage.

The value of milk in human nutrition as an improver of diets, especially for children, is undoubted. Naturally, the poorer the original diet the more obvious the beneficial effect. The addition of 1 American quart (946 ml.) of milk to the diet of negro children in an orphanage in which severe malnutrition existed was followed by spectacular improvement of the milk-drinkers, and later, of the control children when they also were given the benefit of the addition (McCollum, 1924). In this country experiments by Corry Mann in 1910 (Corry Mann, 1939), and some 10 years later (Corry Mann, 1926) showed the benefit of the addition of raw or pasteurised milk to the diet of children. Large-scale experiments planned here by the Milk Nutrition Committee (1938, 1939) showed that the addition of ⅔ pint raw or pasteurised milk in the diet of school children was more beneficial than of ⅓ pint pasteurised milk, but the differences between raw and pasteurised milk were negligible. Similar conclusions about the benefit of milk, whether raw or pasteurised, were reached in Scotland (Orr, 1928; Leighton and Clark 1929 ; Leighton and McKinley, 1930).

It is noteworthy that, in recent years, the effects of the addition of milk have been progressively less striking. It seems likely that the undoubted general

TABLE NV X

NUMBER OF DAY PUPILS AND BOARDERS HAVING MILK ON A NORMAL DAY IN PRIMARY AND SECONDARY SCHOOLS[1]

(Min. Education (1945) and private communication; Min. Education (1950))

		Total No. of pupils having milk ('000s)	*No. of pupils having milk as a percentage of No. of pupils present* (%)
1938-9[2]		(2500)	(55)
1940	July[2]	(2100)	(–)
1941	February	2479	57·6
1942	February	3386	77·9
1943	February	3371	76·8
1944	February	3428	76·3
1945	February	3265	73·0
1946	February	3269	71·5
	June	3370	71·6
	October[3]	4438	92·5
1947	February[4]	3817	87·0
	June	4267	89·0
	October	4395	87·8
1948	February	4366	88·0
	June	4559	88·7
	October	4614	88·3
1949	February	4421	90·2
	June	4620	87·4
	October	4668	87·0
1950	February	4378	85·4

[1] The figures relate to Public Elementary schools and grant-aided Secondary schools, as these terms were understood before April 1945. From 1943 Junior Technical schools are included. Nursery schools are included from June, 1945. Day Special schools are included from June 1948.

[2] These figures are estimated, and relate to Public Elementary schools only.

[3] Milk provided free for all pupils, but limited to ⅓ pint each.

[4] Owing to bad weather the number of children present was abnormally low.

improvement in the diet of the people was mainly responsible for this change. The improvement meant not only that the diets were on the whole more adequate, but that they contained more milk, and it stands to reason that, by the law of diminishing returns, further addition of milk produced less effect.

Table NV IX gives figures for the amounts of milk and milk products moving into civilian consumption. The consumption of liquid milk has risen steadily since before the war, though the total consumption of milk solids has not varied appreciably since 1943. This increase in liquid milk consumption was brought about largely by the *National Milk Scheme* and by increases, in the early years of the war, in the number of school children using the *Milk in Schools Scheme*. Under the *National Milk Scheme* expectant mothers and children under 5 are entitled to a pint of milk daily at a reduced price. Children and adolescents between 5 and 18 years, during periods of rationing, were entitled to half a pint daily and in addition were entitled to an extra ⅓ pint at school. There was a special allowance for invalids. The *Milk Supply Scheme* governs the distribution of milk when the supply is insufficient to meet the demand. Table NV X shows the percentage of children taking milk under the *Milk in Schools Scheme*.

Further reviews on the nutritive value of milk and milk products by Kon and Henry (*JDR* (1951), **18**, 317 ; (1954), **21**, 245, should also be consulted.

Refs.: Blaxter, Kon and Thompson (1946), *JDR*, **14**, 225 (effect of feed on vitamin A); British Medical Association (1950), *Report of the Committee on Nutrition*, London; Campion, Henry, Kon and Mackintosh (1937), *BJ*, **31**, 81 (vitamin D in summer butter); Channon, Drummond and Golding (1924), *A*, **49**, 311 (effect of C.L.O. on fat); Cheldelin and Williams (1943), *JN*, **26**, 417 (riboflavin); Corry Mann (1926), *Spec. Rep. Ser. Med. Res. Coun., London, No.* 105 (raw and pasteurised milk); Corry Mann (1939), *J. R. Publ. Hlth. Hyg.*, **2**, 486 (raw and pasteurised milk); Dearden, Henry, Houston, Kon and Thompson (1945), *JDR*, **14**, 10 (cheese); Drummond, Channon, Coward, Golding, Mackintosh and Zilva (1924), *JAS*, **14**, 531 (effect of C.L.O. on fat); Ford, Gregory, Porter and Thompson (1953), *IDC*, **3**, 1282 (vitamin B_{12}); Henry and Kon (1942), *BJ*, **36**, 456 (vitamin D and season); Henry and Kon (1946), *JDR*, **14**, 330 (proteins of bread and cheese); (1947), *JDR*, **15**, 140 (high preheating of dried milk, proteins); Henry, Kon, Lea and White (1948), *JDR*, **15**, 292 (storage of dried milk); Henry, Kon and Watson (1937), *Milk and Nutrition*, part I, p. 37; Reading, Nat. Inst. Res. Dairying (proteins of pasteurised milk); Irvine, Bryant, Sproule, Jackson, Crook and Johnstone (1945), *Sci. Agric.*, **25**, 845 (cheese); Kon (1934), *JDR*, **5**, 250 (review article); (1936), *JDR*, 7, 192 (review article); (1938), *JDR*, **9**, 242 (review article); (1940), *JDR*, **11**, 196 (review article); (1941), *N*, **148**, 607, (review article); (1943), *JDR*, **13**, 216 (review article); (1944), *J. R. Soc. Arts* **93**, 122 (review article); (1947), *Brit. Med. Bull.*, **5**, 170 (review article); Kon and Henry (1938), *JDR*, **9**, 1 (sterilisation); (1949), *JDR*, **16**, 68 (review article); Kon and Porter (1947-48), *Nutr. Abstr. Rev.*, **17**, 31 (review article); Kon and Watson (1936), *BJ*, **30**, 2273 (effect of light on vitamin C); Leighton and Clark (1929), *L*, **216**, 40 (raw and pasteurised milk for children); Leighton and McKinley (1930), *Milk Consumption and the Growth of School Children*, Edinburgh (raw and pasteurised milk for children); McCollum (1924), *Proc World Dairy Congr.* (1923), **1**, 421 (raw and pasteurised milk); Mattick (1938), *JDR*, **9**, 233 (cheese); Mattick, Hiscox, Crossley, Lea, Findlay, Smith, Thompson and Kon (1945), *JDR*, **14**, 116 (high preheating temperature of dried milk); Mawson and Kon (1945), *L*, **249**, 14 (vitamin C); Milk Nutrition Committee (1937-39), *Milk and Nutrition*, parts I-IV, Reading, Nat. Inst. Res. Dairying (raw and pasteurised milk); Min. Education (1945), Cmd 6644, H.M.S.O, London (milk in schools); Min. Food (1949), Cmd 7842, H.M.S.O., London (consumption of dairy products); Orr (1928), *L*, **214**, 202 (raw and pasteurised milk); Sullivan, Bloom and Jarmol (1943), *JN*, **25**, 463 (cheese); Thompson, Ganguly, Mawson and Kon (1949), *IDC*, 1949, **2**, 238 (vitamin A and riboflavin); U.S. Dept. Agric. (1947), *Misc. Publ.*, No. 636 (vitamin A).

NUTRITIVE VALUE OF FOODS. The chief nutritive characteristics of common foods are given in Table NVF 1 (p. 1131).

OATS. *See* Feeding.

OCCLUSION. The absorption of gases by solids, *e.g.* of oxygen by milk powder.

OCTADECADIENOIC ACID. *See* Linoleic acid ; Fatty acids.

ODOURS. *See* Flavours ; Cheese, p. 168.

OESTROSCOPE. The oestroscope is an instrument for detecting oestrus or heat in cows. (Scott-Blair, Folley, Coppen and Malpress (1941), *N*, **147**, 453 ; *VR* (1941), 29 November). The sticky mucous secretion formed in the cervix of the cow can be collected by inserting the fingers carefully into the vagina, and it is then sucked into the narrow glass tube A by means of the hypodermic, keeping the side-tube B closed with the thumb (Fig. Oe 1). When the secretion fills the whole length of the tube, any excess is cleaned off the end with the finger. Still keeping the side-tube B closed, the secretion is now gently pushed out of the tube by means of a steady pressure on the hypodermic, holding the tube in a horizontal position. The extruded secretion forms a " blob " at the open end of the tube which should not be allowed to fall downwards. As soon as the end of the column nearest B reaches a convenient mark on the scale, pressure is sharply released by removing the thumb from B. When the animal from which the secretion was taken was on heat and at no other time, the secretion will recoil so as to refill the tube almost completely. This property of recoiling when released from pressure in a tube is called " Flow-elasticity ", and should on no account be confused with viscosity (*q.v.*). Cows which are in calf give secretions which show no such recoil; secretions from non-pregnant, non-oestrous cows usually show a very slight recoil but the test is not designed to detect pregnancy as such.

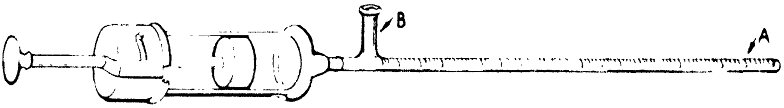


FIG. Oe 1.—*The Oestroscope. In the Simplified Form for Field Use, it Consists Essentially of a Glass Capillary Tube of About* 2 *mm. Bore and About* 11 *cm. Long* (*A*), *Graduated in Millimetres. One End is Cemented Into a Metal Shank which will Fit on to the Nozzle of any " Record " Hypodermic Syringe. Between the Shank and the* 10 *cm. Mark there is an Open Side-tube* (*B*).

The test is particularly useful in winter and with cows which do not clearly show the usual behavioural symptoms when on heat.

The collecting of the samples is not difficult, but it is advisable to have the sampling demonstrated by a veterinary surgeon, since unskilled handling of cows, and especially heifers, can cause serious damage. *See* Breeding; Milk secretion; Pregnancy diagnosis; Rheology.

OHM'S LAW. Current = potential ÷ resistance.

OIDIUM. This name for a genus of moulds is sometimes used as an alternative for *Oospora* (*see* Moulds) and sometimes reserved for parasitic forms.

OILINESS IN MILK. *See* Auto-oxidation ; Copper ; Flavours ; Stability.

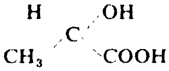
OILS AND FATS. Oils and fats in foods and feeding-stuffs are the esters of glycerol and fatty acids, the lower members being liquid at room temperatures and so regarded as " oils ". *See* Fats ; Fatty acids ; Feeding.

OLEIC ACID. *See* Fatty acids.

OOSPORA. A genus of moulds. *Oospora lactis* or *Oidium lactis* is very common on dairy products and is usually the chief organism of the " scum " on whey. *See* Moulds ; Oidium.

OPTICAL ROTATION AND OPTICAL ACTIVITY. Certain organic compounds have the property of rotating the plane of polarised light, which is light in which the waves are all in one plane. A simple analogy is that of greyhounds jumping hurdles through slits in fences. The greyhounds jump vertically and provided the slits or apertures are vertical the dogs will get over the hurdles and jump round the course. If now the slits are rotated in the plane of the hurdle the dogs will not get through unless they jump in the same angle. Interposing a solution of an optically active compound in the path of a beam of polarised light is equivalent to making the dogs jump at an angle (this is physically impossible but serves as an illustration) and so if they are to clear the hurdles the slits must be rotated to the same angle. By rotating the prism in a polarimeter (p. 847) it is possible to measure this angle and so the amount of substance in the solution.

Only compounds with a carbon atom to which are attached four different atoms or radicals show this activity. Such an atom is called an *asymmetric carbon atom.* Lactic acid is a classical case of this type of compound, consisting of a carbon atom to which are attached a hydrogen atom, a methyl, a hydroxy- and a carboxylic radical :



These four groups can be arranged round the carbon atom as a tetrahedron in two ways which are different, *i.e.* one cannot be turned round to become the other. One modification is then *laevo-rotary* (rotating the plane to the left) and the other *dextro-rotary.* An equal mixture of the two will thus be optically inactive or form a racemic mixture.

Sugars are optically active and this property is the basis of the polarimetric determination of lactose in milk and milk products (p. 600). Organic compounds synthesised in the laboratory are invariably inactive, whereas naturally occurring substances are active if they contain an asymmetric carbon atom.

Refs.: Richmond ; Tyler.

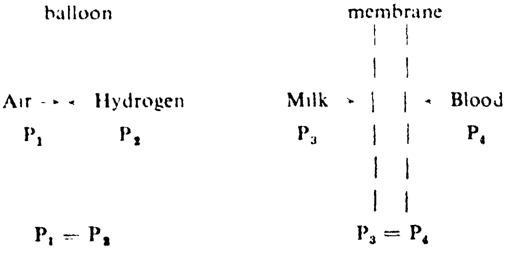
ORGANOLEPTIC PROPERTIES. Properties perceptible to the senses, especially taste and smell.

Ref.: Moncrieff (1951), *The Chemical Senses.*

OROTIC ACID. Uracyl 4(6)-carboxylic acid has been reported to occur in traces in milk.

Ref.: Hallanger *et al.* (1953), *JBC*, **202,** 83.

OSMOTIC PRESSURE. Just as gas in a balloon exerts a pressure on the internal surface of the balloon, so the soluble substances in a solution exert a pressure on a membrane enclosing the solution. In the same way that the gas in a balloon will expand until it is in equilibrium with the air outside, so will the concentration of solutes or dissolved substances in a solution on one side of a permeable membrane change until it is equal in *osmotic pressure* to that on the other side :



The osmotic pressure is controlled by the *number* of molecules or particles, not the weight of solute; thus 100 molecules of size 10 will have 10 times the osmotic pressure of 10 molecules of size 100. It follows that for a given weight, the smaller the molecule the higher the osmotic pressure.

Milk is formed from blood, the two being separated by a permeable membrane, hence they have the same osmotic pressure or, in other words, milk is *isotonic* with blood. The osmotic pressure of blood is remarkably constant although the composition, as far as pigment, protein, etc., are concerned, may vary. The same condition applies to milk, the total osmotic pressure being made up as follows:

Constituent	*Molecular weight*	*Normal concentration* (%)	*Osmotic pressure* (*atmospheres*)	Δ (° C.)	% *of total osmotic pressure*
Lactose . .	342	4·7	3·03	0·25	46
Chlorides . .	58·5 (NaCl)	*c.* 0·1	1·33	0·11	19
Other salts, etc. .	—	—	2·42	0·20	35
Total . .			6·78	0·560	100

Ref.: Coste and Shelborn, *A* (1919), **44**, 158.

This internal or osmotic pressure also defines the difference in freezing-point between the solution and the solvent (water) so that the *freezing-point depression* (p. 485), or Δ above, is a measure of this osmotic pressure. When the composition of milk alters due to physiological (*e.g.* late lactation) or pathological causes (*e.g.* mastitis), it is termed *abnormal milk* but the osmotic pressure and hence the freezing-point remains constant. The most important change is a fall in the lactose and a rise in the chloride content, the latter forming the basis for the Rapid Abnormality Indicator (p. 886).

OVARIAN FOLLICLE. *See* Milk secretion.

OVERRUN. Overrun is a term used to describe the increase in volume of a product, such as ice cream, by the inclusion of a valueless constituent such as air. It is also sometimes used for the incorporation of water in butter. The general equation is

$$\%\ \text{overrun} = \frac{V_1 - V_2}{V_2} \times 100 \quad \text{or} \quad \frac{W_1 - W_2}{W_2} \times 100$$

where V_1 or W_1 = final volume or weight; and V_2 or W_2 = volume or weight of ingredients (or certain ingredients). *See* Butter; Ice cream.

OXIDASES. A general name for oxidising enzymes, now replaced by the term *dehydrogenases*. *See* Enzymes.

Ref.: Sumner and Somers.

OXIDATION. In a general sense, oxidation means the addition of oxygen to a substance; but in biochemistry and physical chemistry the term may have special meanings, especially the loss of hydrogen. Thus the oxidation of an ion consists of an increase in its positive charge or a decrease in its negative charge. Oxidation is of economic importance in the dairy industry in the following ways: (i) production of taints especially oiliness in milk, tallowiness in milk powder and butter, etc., by oxidation of milk fat (lecithins and unsaturated fatty acids) especially if copper is acting as a catalyst; (ii) effect on balance of flora of milk when deteriorating bacteriologically. *See* Auto-oxidation; Enzymes; Flavours; Milk powder; Stability.

OXIDATION-REDUCTION POTENTIAL. The concept of oxidation-reduction potential is concerned with the balance between the oxidised and the reduced forms of chemical substances, *e.g.*

$$\begin{array}{ccccc} 2FeO & + & O & \rightarrow & Fe_2O_3 \\ FeCl_2 & + & Cl & \rightarrow & FeCl_3 \\ \text{ferrous chloride} & & & & \text{ferric chloride} \\ H\,.\,CHO & + & O & \rightarrow & H\,.\,COOH \\ \text{formaldehyde} & & & & \text{formic acid} \end{array}$$

When the reduced and oxidised forms are mutually reversible, a definite potential is set up at an electrode (piece of inert metal) in their solution at any given acidity or *p*H. This potential is controlled by the ratio of oxidised to reduced forms. When these are equal the potential is known as the *normal potential* (E_0) for that system. Examples are:

	E_0 *at p*H 7
Oxygen electrode (1 atmos.)	+ 0·81
Hydrogen peroxide in cultures	0·42
Haemoglobin-methaemoglobin	0·15
Ascorbic acid (vitamin C)	0·08
Pyocyanine	− 0·04
Lactate-pyruvate	− 0·18
Flavins (riboflavin-B_2 complex)	− 0·23
B. coli cultures (minimum)	− 0·40
Hydrogen electrode	− 0·42

See *r*H indicators.

Ref.: Hewitt (1950), *Oxidation-reduction Potentials in Bacteriology and Biochemistry*, L.C.C.

OXIDISED FLAVOURS. *See* Auto-oxidation; Flavours; Milk powder.

OXIDISING AGENTS. These are, or were, used in dairying: (i) as preservatives, *e.g.* hydrogen peroxide in milk (p. 412); (ii) to sterilise plant and utensils, *e.g.* hypochlorites (p. 514); (iii) to prevent gas formation by bacteria, *e.g.* nitrates in cheese (p. 168).

P

PACKAGING OF DAIRY PRODUCTS. The main dairy products concerned are milk, cheese, butter and cream in their various forms. Each may be packed in several different ways according to its special properties and intended method of use, and the following scheme sets out the various products and the types of package normally used. The references are to the other sections in this book where further detailed information may be found.

MILK:	Liquid	Fresh	Bottles Paper carton		p. 80 *et seq.* pp. 164, 314 p. 991
		Sterilised--Bottles)			
	Concentrated	Sweetened condensed	Cans Barrels		p. 287 *et seq.*
		Evaporated	Cans		
	Powdered	Skimmed milk	Cans Barrels		p. 721
		Full cream milk	Cans		
CHEESE:	Natural		Traditional wrappings, p. 184 *et seq.*, 214		
			Cans	Valved cans Hermetic cans	
	Processed		Wrapping in foil Cans		
BUTTER:			Wrapped		p. 142
			Canned		
CREAM:			Bottles		p. 321
			Paper containers		
			Cans		p. 323

Bottles, paper cartons and wrapping materials having been fully discussed elsewhere in the volume; the various types of can used for dairy products will be the only packages whose manufacture will be described in this section. Most cans for dairy products are made from tinplate, but sometimes aluminium and blackplate have been used.

Tinplate Manufacture. ***Rolling the steel sheet.*** (1) *Hot rolling.* Tinplate is made up of thin sheets of mild steel coated on both sides with a layer of pure tin. The sheet steel is made by rolling the ingots or bars of steel by one of two different processes. In the older process known as Pack or Hot Rolling the reduction of the steel bars to sheets of tinplate thickness is done while the metal is hot. Steel bars about 2 to 3 ft. long, 8 to 10 in. wide, and ¼ to ⅝ in. thick, are heated to redness and passed between power-driven rollers until they have been rolled out to the thickness required, usually about 0·01 in. It is not practicable to do this rolling in one stage, so the sheet is doubled over three or four times at intervals during the rolling, and is reheated between each rolling. When rolling is completed the " Pack " of sheets, as it is called, then has its ends cut off to allow the individual sheets to be separated from each other by hand. The sheets are then cleaned by immersion in dilute sulphuric acid, and finally annealed by heating for many hours at 800° to 850° C. protected from the air. This process makes the steel ductile and suitable for can manufacture. After annealing, the sheets are passed while cold through further rollers to smooth their surface, and are again annealed and pickled to make them ready to receive the coat of tin.

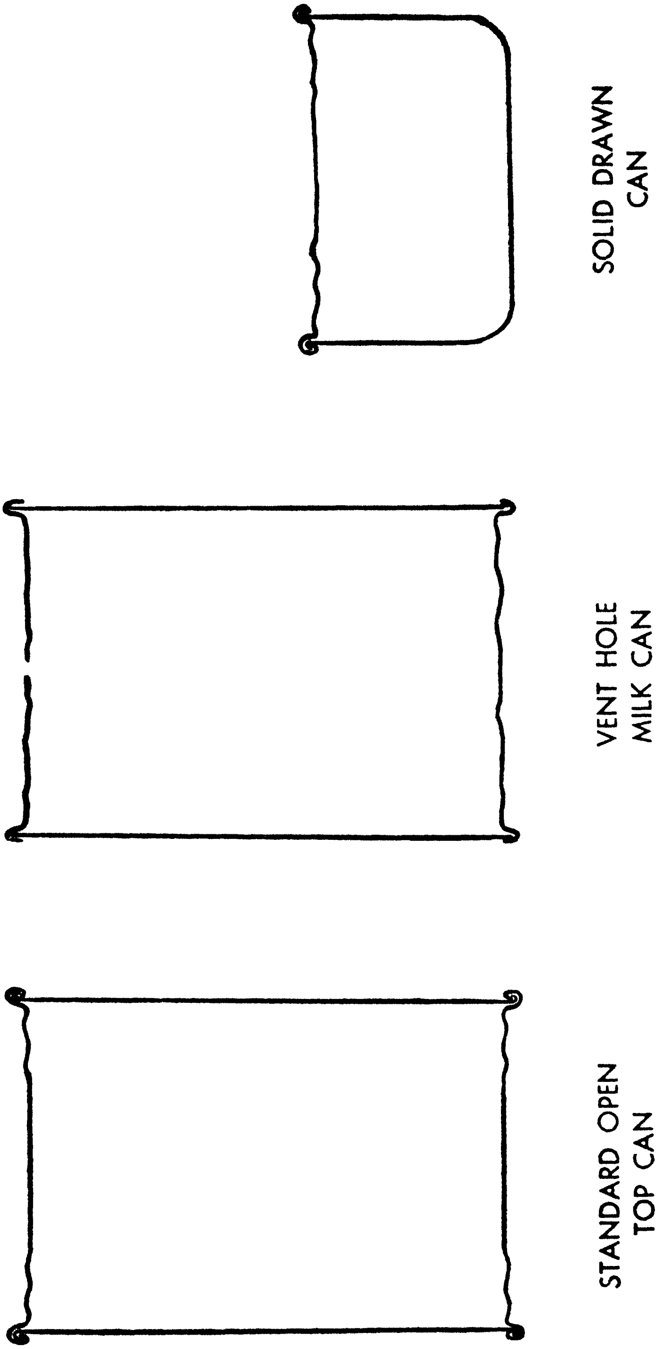


FIG. Pa 1.—*Types of Cans.*

(2) *Cold rolling.* The more modern cold-rolling process starts with a steel ingot about 20 ft. long, 1½ to 2 ft. wide, and 6 to 8 in. thick, taken red hot from the furnace and passed through a series of rollers as it gradually cools down. Such an ingot will produce a strip of steel plate about a mile long, which is formed into a large coil. Annealing is carried out by coiling the hot strip before it has cooled too far, and allowing it to stand before the final reduction to tinplate thickness is carried out at room temperature in a second series of rolling mills. From the cold-rolling mills the strip passes continuously through cleaning baths and is then coiled again and given a second annealing before being finally cut up into sheets of the required size. These are then given a further acid cleaning to make them ready for tinning, which is carried out exactly as with hot-rolled sheets.

Tinning the steel sheet. (1) *Hot dipping.* The process consists in feeding the sheets through a large bath of molten tin. This bath is divided into two parts: the sheets are fed into the molten tin in the first part through the surface of the tin which is covered with a flux of zinc chloride; they emerge from the tin bath through the second part where the molten tin is covered by a layer of palm oil. Running in this palm oil are a series of rollers between which the sheets pass and produce a smooth coating of tin. After tinning the sheets are cleaned to remove the palm oil by passing them between carpet covered rollers in a cataract of bran or sawdust. They are then ready for packing and despatch to the can making plant.

(2) *Electro tinning.* The production of steel in strip form has made possible tinning by means of electro-deposition from solutions of tin salts. The strip of steel is passed at high speed through the plating bath and emerges with a dull matt coating of tin on it. This tin coating is then melted by heating the strip by various electrical methods, and is then suddenly chilled. This produces a brilliant mirror-like finish superior to that obtained by hot dipping, the process being known as flow brightening. By means of electro tinning, much smaller thickness of tin coating can be put on the steel sheet than is possible by hot dipping.

Lacquering the tinned sheet. For most dairy products the cans used are made from plain tinplate, but for certain products the use of an internally and/or externally lacquered can is desirable. Such cans are made by passing the sheets of tinplate through rollers running in a bath of lacquer which apply a thin coating to the sheet. The coated sheet is passed through a heated oven, which causes the lacquer to dry and harden. Such lacquered sheets can then be made into cans exactly as are plain sheets.

Can Manufacture. The cans used for dairy products are of several types: Fig. Pa 1.

(1) ***Open top.*** In this can the body has a soldered side seam, the bottom end being put on by the maker and the top end after the filling of the can by the packer. The method of attachment of the ends to the body is known as double seaming.

(2) ***Vent hole.*** These cans have both side seams and end seams soldered, and both ends are put on by the can maker. The can is filled through a small hole about ⅛ in. diameter in one end, which is subsequently closed by solder.

(3) ***Drawn can.*** The body and bottom end are formed in one piece by pressing them out of a single piece of tinplate. The top end is attached by the packer after the filling of the can by means of double seaming.

(4) ***Valve cans.*** These are " Open-Top Cans ", but a one-way valve is fitted to the lid which allows the escape of gases produced inside the can but prevents the entry of air from the atmosphere.

Open-top cans. The various stages in the manufacture of the O.T. can are as follows: (1) *Slitting.* The sheets of tinplate are cut up by a slitting machine into " body blanks " of the correct size for the can being made.

(2) *Body making.* These body blanks are fed into a machine which automatically takes each blank from a hopper and then trims and forms it into a cylinder, the join or side seam forming the cylinder being made by bending over the edges of the body blank and locking the bent portions together. The locked part is finally soldered by the machine to form an air-tight joint.

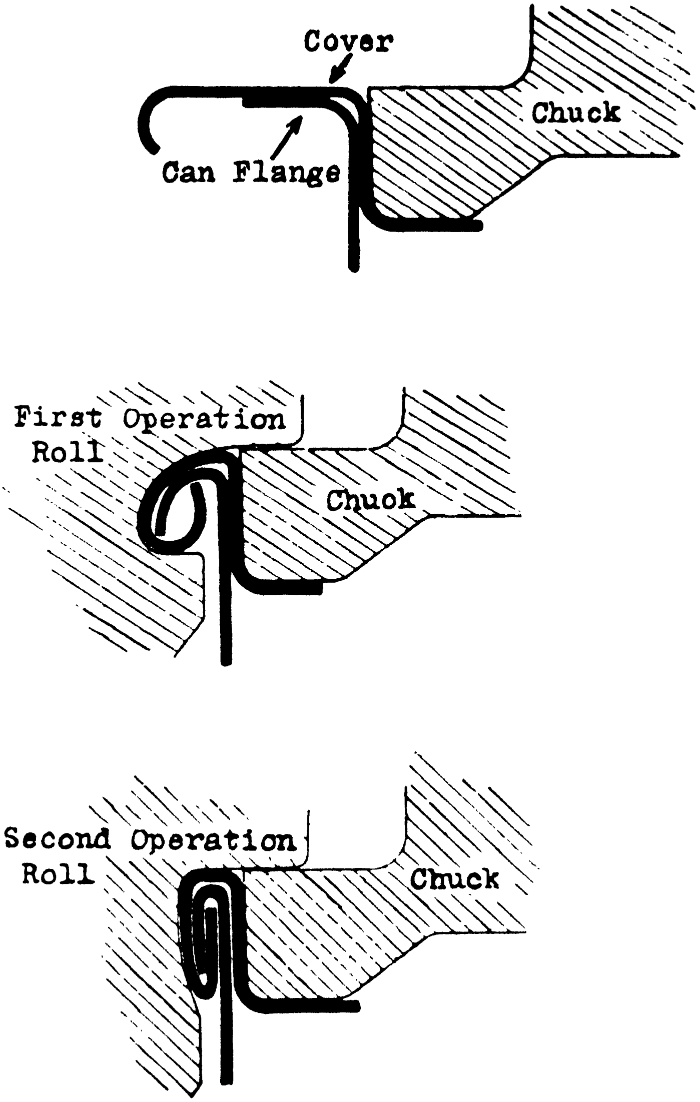


FIG. Pa 2.—*Open-top Can. Seaming.*

(3) *Flanging.* The body cylinders are then passed through a flanger which curls over the top and bottom of the cylinder wall ready to receive the end which has been stamped into the appropriate shape in a separate operation.

(4) *Seaming.* This is the operation of attaching the end onto the body of the can. The joint formed is a mechanical one called a double seam, and is not soldered. The operation takes place in two stages; in the first, the curl round the edge of the end is tucked underneath the flange on the can body, and in the second the whole joint is squeezed tightly together. A rubber compound is applied to the end before it is seamed to ensure that the final seam is air-tight. The top end is put on in a similar manner by the packer after the filling of the can.

A section of the seam at each stage is shown in Fig. Pa 2.

Vent-hole cans. The body of the vent-hole can is made in the same way as that of the Open-Top can, but the flanging operation is omitted and the ends are attached to the cylinder by soldering instead of double seaming. Both ends are soldered in place by the can maker by means of continuous automatic soldering machines which work in conjunction with the body maker.

Drawn cans. Drawn cans are made by stamping a flat piece of metal out of the sheet and then pressing or drawing this by means of a punch and die into a can of the required shape. Such cans may be made out of either tinplate or aluminium, and some of its alloys and, in fact, because of the impractability of soldering aluminium at the speed necessary for the commercial manufacture of Open-Top cans, drawn cans are the only satisfactory hermetically sealed containers for dairy products which can be made of aluminium.

Valved can. This is a standard Open-Top can in one end of which is sealed a one way valve shown in section in Fig. Pa 3. The orifice of the metal of the end is sealed by a rubber diaphragm held by the edges in a separate metal cap and pressed over it. This cap is held in position on the end by curling a projection in the end over the circumference of the cap. As the pressure in the can increases, the rubber diaphragm lifts and allows the gas to escape round the edge of the metal cap.

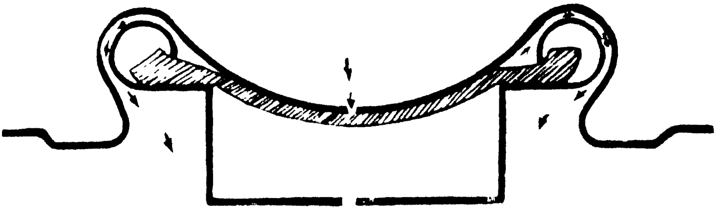


FIG. Pa 3.—*Valved Can.*

Methods of Packing various Dairy Products. ***Milk.*** As indicated above, the packaging of Liquid, Condensed and Evaporated Milk has been dealt with elsewhere. The packing of milk powder, however, needs to be described in more detail. Skim milk powder is not a very labile product, and provided the container used, whether it be a can or a barrel, is able to keep the product from becoming damp, no special technique of packing is involved. Full cream milk powder, on the other hand, is very sensitive to oxidative changes and for a guaranteed shelf life of more than a few weeks needs to be protected completely from contact with moisture and oxygen (*see* p. 721, Milk Powder). This is done by packing in an hermetically sealed container, either in an atmosphere of CO_2 or N_2 or under a high vacuum. The former method is known as gas packing, the latter as vacuum packing. The basic function of these two methods is the same, *i.e.* to remove the air and oxygen from the container, but in gas packing the pressure inside and outside the can is equalised by replacing the air with an inert gas. This considerably simplifies the mechanical problems of closing the container and reduces the strain on it with a consequently decreased risk of leakage.

Gas packing. When the powder has been packed into it the can is then sealed, usually by the method of double seaming described above. A small hole about 1·5 mm. diameter is punched in one end. The gas packing equipment (Fig. Pa 4) consists of a rectangular cabinet with a door at one end which can be sealed hermetically, and the cabinet may be connected through a three-way tap with either a vacuum pump or a supply of inert gas. As many filled pierced cans as possible are then placed in a single layer in the cabinet on a tray and the door closed. The air is removed from the cabinet and consequently from the interior of the cans by turning the three-way tap so as to connect the cabinet with the vacuum pump. With milk powder it is necessary to obtain an oxygen content in the can of less than 2 per cent., and preferably as low as 0·5 per cent., so that the aim should be to reach a vacuum in the cabinet of within ½ in. of the barometer. When this has been done, the cabinet is connected to the tank below it, filled with gas, which is in turn connected with a cylinder of inert gas. This tank

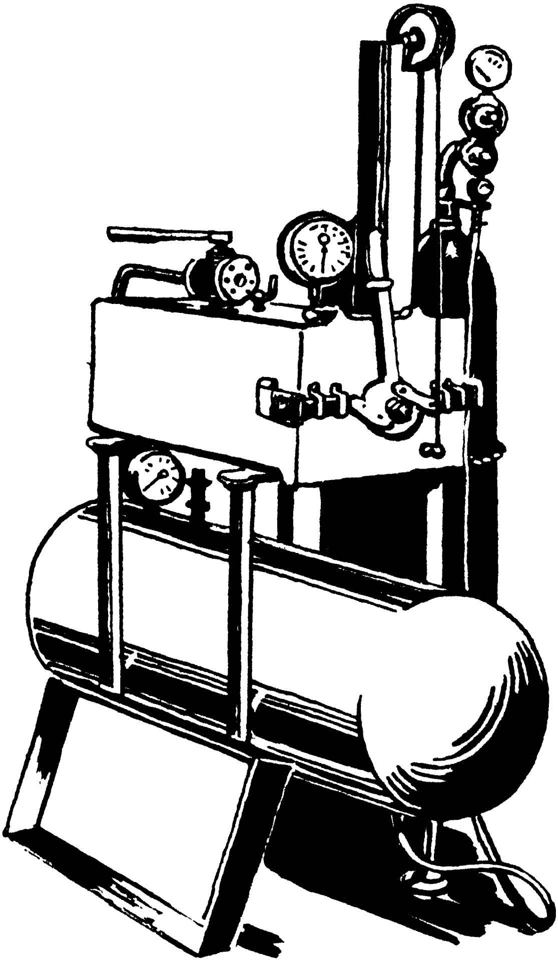


FIG. Pa 4.—*Gas Packing Equipment.*

is necessary particularly when CO_2 is used to allow for the slow expansion of the gas from the cylinder, and so to prevent freezing of the outlet valve. The cabinet is allowed to fill with gas to an excess pressure of 1 to 2 lb. p.s.i. and the cans are then withdrawn and the small holes quickly soldered up. Such relatively simple equipment has an output of about 10 to 12 ½-lb. cans per min. Fully automatic equipment is also made to carry out a similar operation, but it is much more complicated mechanically. With such equipment, each can is treated individually and passes in turn through a series of small chambers in which the air is withdrawn from it, the can is filled with gas and is finally hermetically sealed before coming out into the atmosphere.

Vacuum packing. For the commercial vacuum packing of cans a similar machine to the above fully automatic gas packer is necessary, but since the gassing step is eliminated the operation is somewhat simpler mechanically, the end being double seamed onto the can while the whole is held under vacuum.

Cheese. By far the most important type of package used for cheese is the traditional wrapping peculiar to each variety, and which is fully described in its many and varied forms elsewhere in this book. Other packages are metal cans and metal foil (B.S.I. 1948 and 1950). Naturally ripened cheese may be packed into hermetically sealed cans and then subjected to heat treatment at 212° F. or higher in order to prevent any further biological or enzymic changes taking place, but this method, with many types of cheese, markedly alters the characteristic flavour and texture of the product, and is not widely used.

Another form of can for cheese incorporates in one end a one-way valve which allows the escape of gas produced inside the can and prevents the entry of air. Cheese packed in such a can is not subjected to any heat treatment after packing and sealing the can, and the ripening processes continue in it. The cheese, made in a press of suitable dimensions, is put straight into the can but may be wrapped in parchment. The oxygen remaining in the can is used up and the gases evolved by the cheese produce an atmosphere which prevents the growth of moulds, and since there is little loss of moisture, hardly any rind is formed and there is little shrinkage. Cheese packed in this way will keep for long periods, and retains more nearly its traditional flavour than does the heat-treated canned product. The appearance, however, may be markedly changed.

Processed cheese (*see* p. 199), on the other hand, is sometimes filled into hermetically sealed cans instead of being wrapped in the more usual aluminium foil. The processed cheese should be heated to 170° F. for 30 min. and while still molten filled into the can leaving as little headspace as possible and immediately sealed. Sometimes a paper liner is used to facilitate the removal of the cheese from the can. The can is then heated, usually for about 30 min. at 230° F. in order to destroy mould spores on the outside surfaces of the cheese and on the inside of the can. The same heat treatment is, therefore, given to all sizes of can. The cans should then be rapidly cooled in water. Such a product will keep in good condition for very long periods.

Butter. Only two types of package are normally used for butter, the parchment wrap and the metal can. The keeping quality of butter depends largely on the original quality and cleanliness of the raw materials from which it was made and on the temperature of storage. Its shelf life is not extended to any very great extent by the method of packing, the main function of the package being to protect the butter from atmospheric contamination and mechanical damage. The wrapping paper as received from the mill is usually free from any significant degree of infection and provided a tight wrap is obtained and the butter does not exude excessive amounts of moisture, little trouble due to the package will occur. A considerable amount of work has been done on the effect of incorporating various antioxidants into wrapping paper for butter and on the effect on butter of the nature of the surface of the tinplate used in metal containers, but so far this has had little commercial application (Dahle and Josephson; Lea, 1946).

In packing butter into cans it is essential to pack it as tightly as possible, so as to leave no air pockets where micro-organisms might grow or rusting of the containers might take place. The can is then sealed hermetically and gets no further heat treatment. No internal paper liner should be used, as this may provide a favourable medium for the growth of moulds.

Cream. Cream for canning must (since 1951) contain 23 per cent. fat and is prepared by blending separated cream and milk till the desired result is obtained. A stabiliser, such as sodium citrate. is added and the whole is then mixed and heated to about 160° F. The acidity of the cream used should not be more than about 0·15 per cent.

After heating, the cream must be homogenised at a pressure of about 3000 lb. p.s.i. and filled hot into the can and closed and processed immediately.

An agitating retort either of the continuous or batch type should be used for sterilising the cans which for the 6 oz. size must be heated for 20 min. up to 240° F. and 20 min. at 240° F. and then rapidly cooled in water.

Insufficient heating will lead to bacterial spoilage (*see* p. 323), one particular trouble with canned cream being the development of a bitter flavour (McMaster, 1932). Overheating, on the other hand, will result in deterioration of the colour, flavour and texture of the cream.

See Butter; Cheese; Condensed and evaporated milk; Cream, canned; Milk powder; Stability.

Refs.: Dahle and Josephson (1937), Paper No. 777, Pennsylvania Agricultural Experiment Station; Lea (1946), *JSCI*, **65**, 136; McMaster, *Camden Annual Report* (1932-33), p. 71; *FIM*; Sanders (1949), *CI*, p. 151; Oswin, *ibid.* 183; Browne (1949), *Modern Packaging Encyclopedia*, N.Y.; B.S. 1133 (1951), *Packaging Code*; Molloy (ed.) (1952), *Packaging and Display Encyclopedia*; B.S. 1436 (1948) (coated tinfoil); B.S. 1683 (1950) (coated aluminium).

PALATABILITY. The attractiveness of a food or the response of the consumer depends on a number of factors, *e.g.* (i) the general personal liking of the individual for the class of foodstuff in question; (ii) the physiological condition of the individual; (iii) the appearance (colour, texture, freshness, etc.) of the food; (iv) the aroma (volatile acids, ketones, etc.); (v) the taste (*p*H, salts, etc.). The whole question of palatability is thus a highly subjective one and is of the greatest importance in the grading of dairy products (pp. 491 and 493). Taste and aroma (commonly called "smell") are termed "organoleptic tests" and together constitute *flavour*. Thus in grading butter or cheese, separate marks may be given for body, texture, and flavour. *See* Butter; Cheese; Flavours; Grading; Milk powder; Stability; Sterilised milk.

PALM KERNEL CAKE (AND OIL). The fruit of a species of palm when subjected to pressure or to fat solvents provides a cake or meal which is a valuable food for dairy cattle. The extracted oil is used for the manufacture of margarine. *See* Feeding.

PALMITIC ACID. *See* Fatty acids.

PALMITIN. Glyceryl tripalmitate.

PANCREAS (SWEETBREAD). An important abdominal gland secreting (i) lipase and trypsin (through ducts); (ii) insulin (internal secretion). *See* Digestion in the ruminant; Enzymes; Glands; Hormones; Milk secretion.

PANCREATIN. The general and commercial name for the proteolytic enzymes (trypsinases) of the pancreas. *See* Enzymes.

PARACASEIN. It was formerly thought that when rennet acted on the dispersed casein in milk it split the molecule in two. American nomenclature referred to these two substances as *casein* and *paracasein*, whereas the classical English nomenclature was *caseinogen* and *casein*. It is now customary to use the term "paracasein" for the protein which is precipitated when milk is treated with rennet, but views on the chemical changes involved have been altered by the work of Berridge. *See* Enzymes; Rennet.

PARASITE. An organism whose existence is dependent on the life of another organism.

PARATYPHOID FEVER. *See* Diseases.

PARCHMENT PACKING. Parchment is used for packing butter in boxes and casks and can be a source of mould spores leading to spoilage in the butter. This trouble can be minimised by treating the parchment for 24 hr. with saturated brine. *See* Butter; Packaging.

Refs.: B.S. 1820 (1951); Arup (1931), *A*, **56**, 149.

PARMESAN. *See* Cheese, p. 197.

PASCAL'S LAW. A fluid under pressure exerts equal pressures on equal surface areas.

PASSBURG PROCESS. This German vacuum roller drier consists essentially of a steam-heated drum partly immersed in the milk which is drawn into the vacuum chamber. A knife removes the film of dried milk in the usual way, the capacity being from 350 to 400 gal. per hr. *See* Milk powder.

PASTEURISATION. Probably no subject outside religion and politics has been the cause of more prolonged and bitter controversies than the proposal compulsorily to pasteurise all milk. Possibly there is some subconscious mystical feeling that milk coming from the mother's body is sacred, in much the same way as the cow and its milk are sacred to some races for religious reasons. Some people are fond of using the phrase " the biological property of milk ", and refer to milk as a " living fluid ". These high-flown phrases are unsupported by any scientific evidence. The value of milk is, as far as we know, the value of its constituents—fat, protein, minerals, vitamins, etc.—and no more. The only living things in milk are bacteria, some of which can cause death, and the body cells or leucocytes, which increase greatly when the udder becomes diseased. The conception that milk is a " living fluid " in any special sense is unsupported by any evidence.

Although Pasteur was the first to study scientifically the preservation of liquid foods by *moderate* heating, the value of heat for this purpose was, of course, known to the ancients. In 1765 Spallanzani observed that boiling preserved meat extract and in 1782 Scheele preserved vinegar in this way. Pasteur worked on wine in 1862-64 and on beer in 1870. In 1873 Jacoby (New York) recommended cooking to stop the souring of milk, and in 1886 Soxhlet advised the boiling of milk for infant feeding. Theobald Smith in 1899 determined the thermal death point of the tubercle bacillus in milk as 140° F. for 15 min.

It is important that the general public should know exactly what is meant by the pasteurisation of milk and that this information comes from unbiased sources. It is of interest to note that a survey of opinions amongst farmers once recorded a 99·9 per cent. vote against the proposal to pasteurise milk; a similar survey among housewives elicited the fact that 99·9 per cent. did not know what was meant by the heat treatment of milk.

The term " pasteurisation " is coined from the name of Pasteur, who showed that unwanted fermentation in wine could be prevented by raising the temperature to from 122° to 140° F. for a short time. The method was soon afterwards applied to milk and was slowly developed in the larger towns of America and Europe for the purpose of improving keeping quality. The fact that pasteurisation destroyed pathogenic organisms, and so rendered milk safe, was in the early days a secondary consideration. Medical bacteriologists were naturally more interested in the public health aspects of pasteurisation than its commercial advantages, and it is not surprising that a process which is simple and practicable and achieves such outstanding effects should have increased steadily in popularity and usefulness.

In considering the history of the pasteurisation controversy it is important to remember that, although scientists everywhere agreed fairly closely on the necessary degree of heat treatment, the process was for long very loosely controlled in commercial practice. Milk was frequently either overheated or underheated, so that it either gave a cooked flavour or was found to contain viable T.B. In addition, properly pasteurised milk was (and sometimes still is) frequently badly contaminated by unsterile plant, so that its keeping quality was not appreciably improved, and on occasions was actually decreased.

Temperature-time conditions. Fortunately, all common pathogenic organisms likely to occur in milk are killed by a relatively mild heat treatment which has only a very slight effect on the physical and chemical properties of milk. The most resistant organism is the tubercle bacillus, and bacteriologists agree that normally it is killed by heating milk for 10 min. at 145° F., a temperature at which we can sip tea with pleasure (Table P 1).

TABLE P I

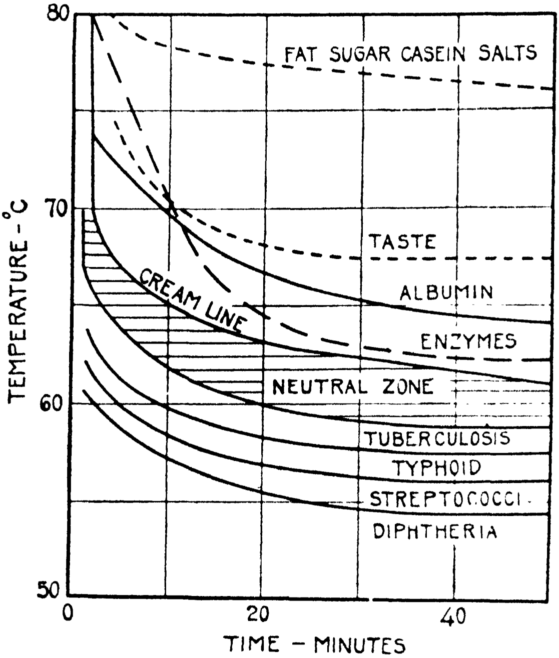
TIME-TEMPERATURE CONDITIONS NECESSARY TO DESTROY BOVINE TUBERCLE BACILLI IN MILK (NORTH AND PARK, 1927)

Temperature		*Time*
(*° F.*)	(*° C.*)	(*min.*)
150	(65·6)	2
145	(62·8)	6
142	(61·1)	10
140	(60·0)	10
138	(58·9)	20
136	(57·8)	30
134	(56·7)	40
132	(55·6)	60
130	(54·4)	60

Bovine T.B. is also by far the most dangerous pathogenic bacterium in milk, and in 1938 was considered to account annually for about 2000 deaths, mostly of non-pulmonary T.B. in children. We can, then, regard T.B. as the index organism for pasteurisation—any heat treatment which destroys T.B. can be relied upon to destroy all other pathogens in milk. It is extremely fortunate that none of the pathogens of importance in milk form spores. If only one of these produced spores, even boiling for several hours could not be relied upon to kill the spores and make the milk safe. We should have to autoclave all milk in order to make it safe—a process which turns milk slightly brown and markedly affects the flavour. Happily this is quite unnecessary. Complete safety can be assured by heating milk to 145° F. (62·8° C.) for 30 min.—a treatment which has only a slight effect on vitamins B_1 and C, and a negligible effect on cream line, palatability, and denaturation of the albumin (Fig. P 1). These last three properties are the first to be affected if the heat treatment is too drastic.

We may define pasteurisation in general terms as " any heat treatment which secures the certain destruction of unwanted micro-organisms without impairing the commercial value of the product ".

The pasteurisation of milk is a special type of pasteurisation, and we may define this for consumer milk as " any heat treatment of milk which secures the certain destruction of T.B. without markedly affecting the flavour or the cream line ". If the milk is to be used for another purpose, the definition may have to be altered. Thus for cheesemaking we may define pasteurisation as " any heat treatment which secures the certain destruction of any micro-organisms likely to cause faults in the cheese (*e.g.* holes or taints by coliform organisms) without markedly affecting the formation and character of the rennet curd or otherwise producing undesirable features in the mature cheese". Pasteurisation usually destroys about 99 per cent. of the bacteria in bulk milk. The milk of certain producers who do not properly clean and only " half sterilise " their milking machines and utensils may be rich in thermoduric organisms. Pasteurisation may kill only a half or in some cases a very small proportion of the total flora of such milk. Fortunately, the organisms surviving pasteurisation are non-pathogenic and most of them have little effect on the keeping quality of milk. When pasteurised milk sours or deteriorates rapidly it is almost invariably due to post-pasteurisation contamination.



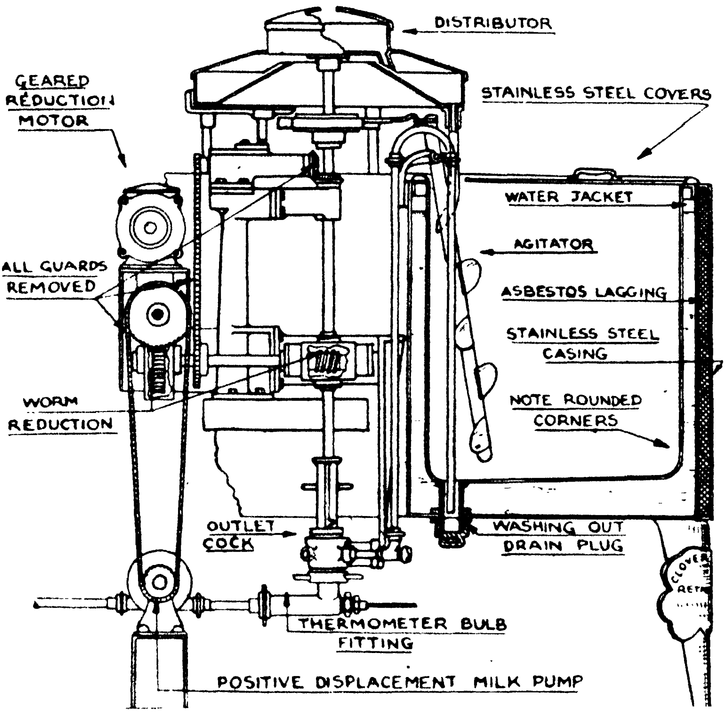
Effect of heating on the constituents of milk and on certain pathogenic bacteria. From North

FIG. P 1.—*Temperature Time Graph.*

The holder method. In this country until July, 1941, there was only one definition of pasteurisation—heating milk to 145°-150° F. for 30 min. and cooling immediately to less than 55° F. This treatment has an ample margin of safety, and other countries are content with somewhat milder treatments.

Where the milk is heated and then pumped into a holding vessel and finally pumped out and cooled, the equipment is commonly called a " holder " plant. Holder-pasteurising equipment is fast disappearing in this country, especially in the larger dairies. If the heating, holding, and cooling all takes place in one vessel, the equipment is commonly called a " batch pasteuriser ". The capacity is usually small, *e.g.* 50 or 100 g. A popular type in smaller dairies is the " Clover Leaf " (Fig. P 2). Typical plants are illustrated in Fig. P 2*a* and P 2*b*.

The new type " Desco " stainless steel batch pasteuriser (Figs. P 2*c* and P 2*d*), utilises the principle of a low-pressure hot water heated jacket surrounding the milk pan. Single, double or treble silent injection heaters according to milk capacity are arranged to provide a high velocity water movement in the jacket which opposes the general flow direction of the milk in the inner pan due to the agitator paddle. In this way a high rate of heat transfer is claimed without burning the milk on the surface of the pan. Other features of this pasteuriser, include domed stainless steel covers to prevent condensation entering the pan, and a flush-mounting sanitary type plug cock with special fluting arrangements to prevent any unpasteurised milk seepages from reaching the outlet connection. The vat is normally equipped with both a mercury in steel temperature recorder having single degree Fahrenheit calibration and a dial type indicating thermometer. Both instruments are fitted with stainless steel bulbs of sufficient length to permit temperature readings for capacities down to approximately ¼ maximum for each size of vat. Research into the mechanical properties of capillaries has resulted in the use of special polythene sheathing embedded with wire which is claimed to be almost indestructible. In addition, this form of capillary covering presents a sanitary finish and furthermore is hermetically sealed against the ingress of moisture, thus diminishing the possibility of capillary corrosion.



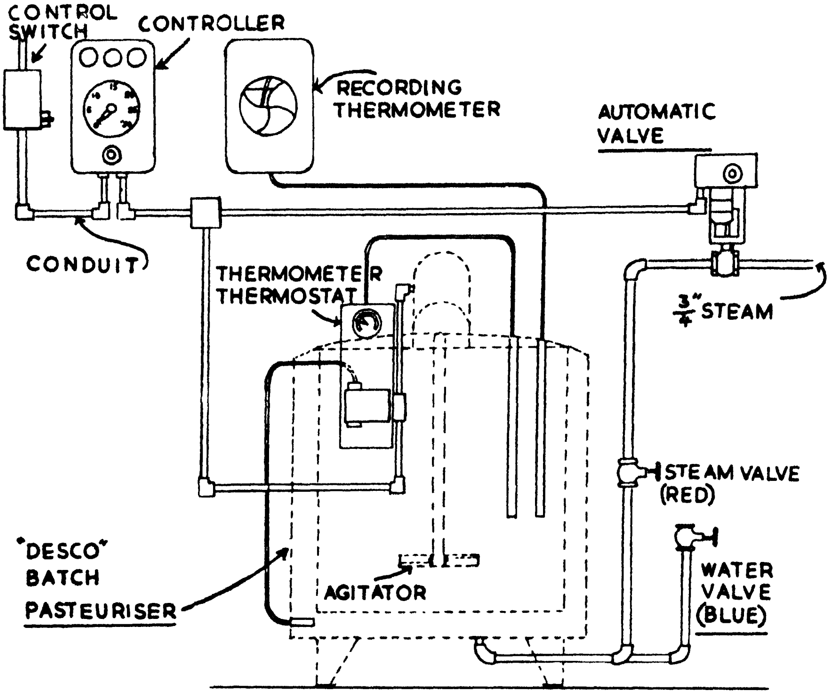
[*By courtesy of G. S. Clayton Ltd.*

FIG. P 2.—" *Clover Leaf* " *Pasteuriser.*

Fully automatic temperature and cycle control has been designed as a standard fitting for the pasteuriser with the express purpose of eliminating as far as possible the human element, and it is claimed that nothing more than filling with milk and depressing a push button is necessary for complete pasteurisation. The system functions automatically by raising the milk temperature to 145° and holding for ½ hr. A visible signal indicates that the pasteurising temperature has been reached, and a further indication is given ½ hr. later that processing is completed and that steam has been shut down. The agitator continues to run until manually stopped by depressing the " off " button.

It is not possible to open the steam valve electrically until the controller hand is reset to zero. Any interference with the timing cycle, which commences at a milk temperature of 145°, will result in the shutting down of steam and the isolation of the controller until the process of initiating the operation has been repeated.

The controller can also be interconnected with a warning bell which normally rings at the completion of pasteurisation. A simplified version of the control system can also be offered which modulates the steam supply according to temperature conditions but does not include the time cycle feature or agitator control.



INSTALLATION ARRANGEMENT OF "DESCO" BATCH PASTEURISER AUTOMATIC TEMPERATURE CONTROLS

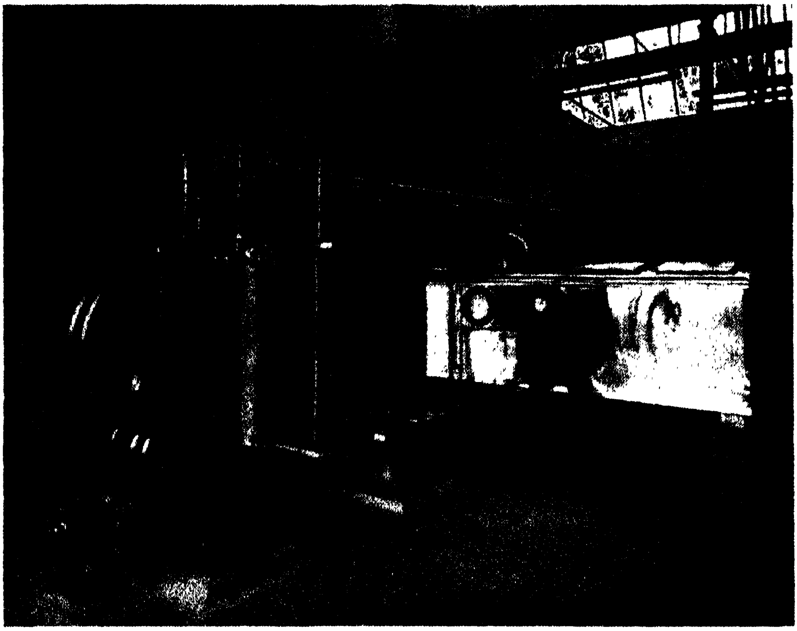
[*By courtesy of Dairy Supply Co., Ltd.*

FIG. P 2*d*.

High Temperature-Short Time Pasteurisation. This method of pasteurising milk has expanded so enormously in the last few years that the classical holder method can already be considered obsolete. The H.T.-S.T. method has found such wide acceptance and has proved to have so many advantages over the holder method that it is now regarded as the normal method of pasteurising milk.

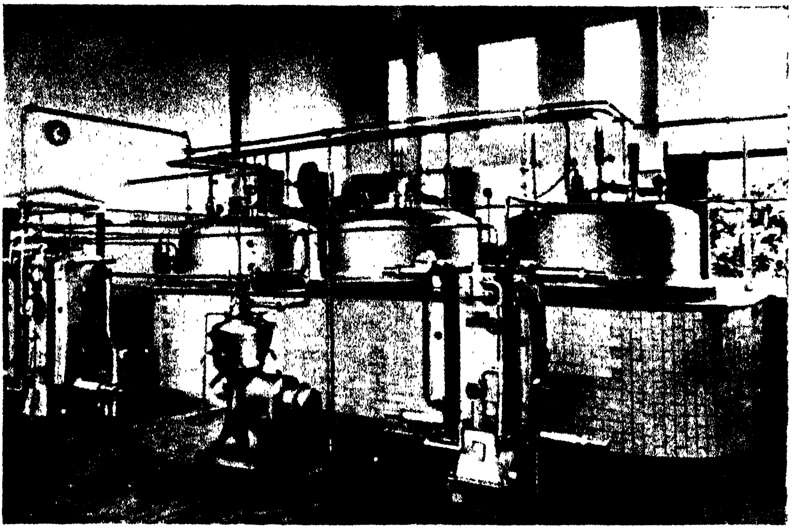
Its growth in the last few years has been so rapid that over 50 per cent. of all dairies pasteurising milk now employ H.T.-S.T. plant. Indeed, it is no secret to say that if the H.T.-S.T. method had not been permitted during the war, the dairy engineering industry would have been unable to maintain the pasteurising equipment for the country's milk supply. On the whole it is the bigger dairies who have gone over to H.T.-S.T., so that roughly 75 per cent. of all heat-treated milk is now processed by this method. Practically all large pasteurising depots now employ the high temperature-short time method.

From a commercial point of view we may consider the pasteurisation of milk to be that heat treatment which ensures the destruction of the tubercle bacillus in naturally infected milk but has the minimum possible effect on the cream line. It must be emphasised that experimentally it is very difficult to raise the temperature



[*By courtesy of Aluminium Plant and Vessel Co. Ltd.*

FIG. P 2 (*a*).—*Holder Pasteurisation Plant.*



[*By courtesy of Hiron and Rempler Ltd.*

FIG. P 2 (*b*).—*Pasteurising Plant with Holding Vats.*

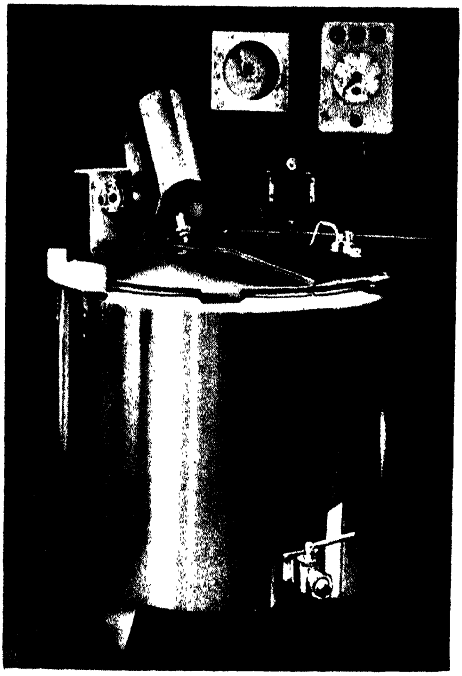
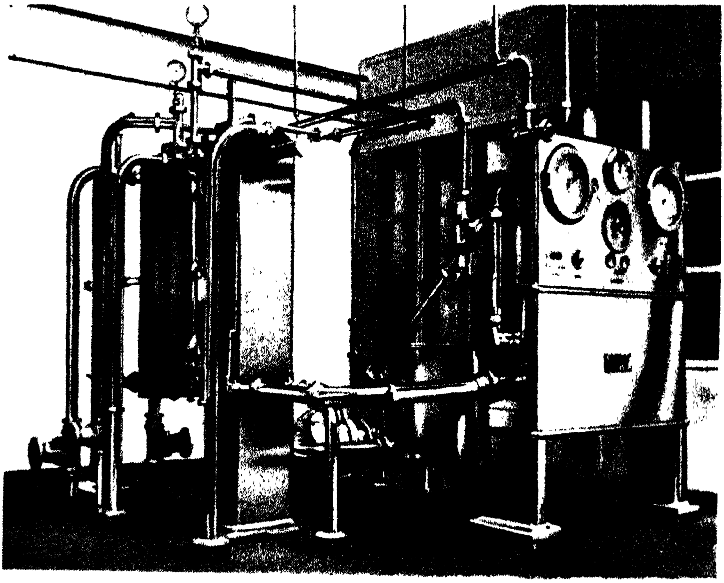


FIG. P 2 (*c*).—" *Desco* " *Batch Pasteuriser.*

[*By courtesy of Dairy Supply Co. Ltd.*



[*By courtesy of Aluminium Plant and Vessel Co. Ltd.*

FIG. P 4.—*All Stainless Short Time Pasteurising Plant.*

of a liquid rapidly to a given point, hold it for a known short time, *e.g.*, 15 sec., and then rapidly cool it. For a holding period of ½ hr. a matter of 30 or 60 sec. for heating and cooling is relatively unimportant, but for a holding period of 15 sec. it is obvious that for accurate scientific investigation the times of heating and cooling must be of the order of 1 sec.

The approach to the problem of H.T.-S.T. pasteurisation must, therefore, necessarily be empirical. What is done in practice is to heat, hold, and cool the milk in such a way that the milk then reacts in a certain way to certain tests. It is impossible to subject the whole of a given quantity of milk to identical conditions. In other words, whether in the laboratory or in the plant there will always be varying proportions of milk receiving varying treatments. The absolute essential is that all the milk shall have received at least a certain minimum treatment. This means in effect that varying proportions of the milk will have received treatments which are excessive to varying degrees. To sum up, therefore, we may say that our temperature-time conditions can be much more accurately controlled the longer the holding time. The high temperature-short time process rests entirely on an empirical basis and no one has yet succeeded in subjecting any quantity of milk to a temperature of, say, 161° F. for exactly 15 sec.

The high temperature-short time process may be defined as a treatment which involves heating milk at a temperature of 160° to 162° F. for from 12 to 20 sec. The Ministry of Health Order in this country requires heating to at least 161° F. for a nominal period of 15 sec. We may now consider the effect of the process on ordinary bulk milk.

(i) ***Pathogenic micro-organisms.*** As with all methods of pasteurisation, the tubercle bacillus is considered as the index organism. Experimental data for the destruction of T.B. by the H.T.-S.T. process is as yet very scanty, but what evidence there is suggests that T.B. is destroyed in milk heated to 158° F. for 15 sec. nominal. Experiments on other disease-producing bacteria such as streptococci, the typhoid group, etc., indicate that much the same relationship holds as with the holder process, *i.e.* different groups of bacteria are destroyed at various heat-treatment levels according to the known data about their thermal death point. In practice we can assume that if T.B. is destroyed all other pathogens will likewise be destroyed.

TABLE P II

TIME-TEMPERATURE RELATIONSHIPS IN MILK

(Holland and Dahlberg (1940), *N. Y. St. Tech. B.*, 254)

Time	*Phosphatase*	*Coli*	*Cream line*
60 min.	141·5	139	141
30	144	142	144
20	145·5	144	145·5
10	148	147	148
5	150·5	149·5	150·5
2	153·5	153	154
1	156	156	157
30 sec.	159	159	159
15	161	162	162
5	165·5	166	166
2	168·5	169	170

The phosphatase test, which is now accepted as a reliable test to prove that milk has been sufficiently heat-treated to destroy the tubercle bacillus, becomes negative when milk has been heated to 160° F. for 15 sec. Cream line, which is the next test or property to be affected, is appreciably damaged if the temperature rises even a little above 162° F. We see, therefore, in this series of temperature relationships exactly the same order of relationship as with the holder process—namely, that T.B. is destroyed at a heat treatment slightly milder than for phosphatase, and phosphatase at a heat treatment slightly milder than for cream line (Table P II).

These figures represent those temperatures at which coli is destroyed, cream line begins to be reduced and phosphatase is inactivated (official standard test) in ° F.

(ii) ***Bacterial counts.*** It is not possible to lay down categorically how the H.T.-S.T. process compares with the holder method from the point of view of bacterial counts. Some experiments seem to show that the holder method is slightly superior and some that the H.T.-S.T. method is slightly superior. These differences are, of course, usual in bacteriological work, and, indeed, are not surprising in view of the variables which must be considered. Different types of plant, handled in different ways and with different milk supplies, must inevitably give slightly different results. Broadly speaking, we may safely assume that the H.T.-S.T. method gives much the same result as the holder method, and, indeed this is not surprising when we consider that the conditions for H.T.-S.T. have, in fact, been chosen in order to give results similar to those obtained by the holder method.

Thermoduric organisms. We may define these as the bacteria which survive the holder pasteurisation process. Broadly speaking, much the same types survive the H.T.-S.T. process as the holder, but there is some indication that differences may occasionally occur. It is obvious that the lag in temperature rise through a bacterial cell wall will be of quite different significance in the holder method than in the short time method. One might expect that cells which have an abnormally high resistance to heat would have a slightly higher chance of surviving the short time method. For example, there have been many reports in the last few years of heat-resistant coli surviving the H.T.-S.T. process, and some workers have been inclined to attribute this to a slight inferiority in the short time method. What we do not know is whether there has been, in effect, an increase in the numbers of heat-resistant coli in our milk supplies. It is naturally very difficult to get any reliable data on such matters. Under certain conditions bacteria, and especially bacterial clumps, may become coated with some protective material, *e.g.* denaturated protein, precipitated calcium salts, etc. Such membranes will naturally increase the time necessary for heat to penetrate the bacterial cells and such conglomerates may therefore stand a better chance of surviving in the H.T.-S.T. process than in the holder. Filtration or clarification may play a far more important part in controlling thermoduric counts in the H.T.-S.T. process than has generally been realised. (*See* pp. 229 and 970.)

Thermophilic bacteria. Thermophils may be defined as organisms growing at temperatures in the region of 60° to 65° C. The outstanding characteristic of these organisms is that their thermal death point is only slightly higher than their optimum growth temperature. In other words, a rise of 2° or 3° C. in temperature may convert the optimum growth temperature to the thermal death temperature. It is quite safe, therefore, to assume that the ordinary thermophils will not proliferate under high temperature-short time conditions (71° to 72° C.), and in fact outbreaks of thermophilic growth are unknown in properly controlled and managed H.T.-S.T. plants. (*See* p. 1025.)

(iii) ***Odour and taste.*** From the commercial point of view these properties are as important as bacterial taints such as souring, as no matter how low the bacterial count may be, unless the milk is palatable to the consumer it will not be a marketable article. Criticisms have been made from time to time that milk processed by the H.T.-S.T. method has a characteristic taint which is unpleasant to the consumer. It is difficult to describe this, but it may safely be asserted that any such taint, if real, is not due to the method but due to other factors. It is probable that the factor chiefly concerned is the presence of copper in the metal of which the equipment is constructed, and it is surprising to find that some dairy engineering firms are still using copper alloys which may give rise to copper taints in milk. Most plant is now constructed of stainless steel, and all dairies would be wise to insist on this material for all equipment coming into contact with milk.

(iv) ***Cream line.*** In the early days of the milk bottle, cream line became a valuable advertising tool for those interested in the sale of milk in glass bottles. The changeover from the holder method to the H.T.-S.T. method undoubtedly adversely affected the cream line at first. During the war, housewives were less inclined to pay attention to cream line, because their chief interest was in getting the maximum quantity of milk possible from the roundsman. Now that competition once more plays its part in milk sales there is little doubt that cream line is again an important factor.

Under the extremely difficult conditions under which the dairy industry operated in wartime it was not possible to pay too fine attention to the limits of control in pasteurisation plants, and managers very rightly allowed themselves a safety margin in order to ensure that as far as possible pasteurised milk always had a satisfactory keeping quality. Thus milk was quite commonly heated up to 164° F. or even higher to attain this objective. Combined with this excessive heat treatment was the turbulence factor. By far the greatest majority of our H.T.-S.T. plants in this country are of the plate type, in which every effort is made to ensure maximum turbulence in the heat exchanger so that as far as possible all particles of milk receive the same heat treatment. Turbulence at high temperatures is well known to have a destructive effect on cream line, and this has certainly been borne out by experience with H.T.-S.T. plant during the war. Whereas the holder method was found to give a destruction of about 14 per cent. the H.T.-S.T. method, with a nominal holding time of 15 sec. at 162¼ F., gives a destruction of about 30 per cent., and at a temperature of 163° F. a destruction of 50 per cent. It is not surprising that the public formed the conclusion that during the war the milk was of poorer quality than pre-war, because the consumer instinctively judges the richness of milk by the cream line in the bottle. The 1949 Regulations (*see* p. 609) reduced the minimum temperature for the H.T.-S.T. process from 162 to 161° F. This permitted improvement of cream line, or a reduction of the loss from about 25 per cent. to about 10 per cent. (*See* p. 325.)

Advantages of the H.T.-S.T. Method. (i) The amount of plant and floor space required is much less than with the holder method. Not only does this give obvious economic advantages, but there are other practical aspects linked with this. For example, less plant for a given gallonage means less plant to buy, maintain, and clean. The importance of the last of these cannot be exaggerated, as during the war the limiting factor in most dairies was the quality and quantity of labour required for plant cleaning. The poorer keeping quality of our wartime milk can, in practically all cases, be attributed to shortcomings in the cleaning of plant.

(ii) Milk is ready for retail distribution much quicker than with the old holder method. This will be obvious when it is realised that under the batch or holder method a certain volume of milk, *e.g.* 200 gal. had to be collected, raised to 145° F., held at this temperature for ½ hr., and then cooled before it could be bottled and issued for distribution. With the H.T.-S.T. method, provided that the rate of intake is known, the plant can be started with very little milk in the tank and the actual warming, holding, and cooling of the milk take only a matter of a minute.

On the average it may be assumed that with the H.T.-S.T. process, milk can be sent out ¾ hr. earlier than with the holder method.

(iii) The H.T.-S.T. method gives greater simplicity in that the whole of the treatment of the milk takes place in one plant which is compact and all of it is under the eye of the operator.

(iv) It is cheaper than the holder method for obvious reasons.

(v) Although in the early days of H.T.-S.T. its critics laid considerable emphasis on the fact that it was a delicate precision method, and therefore not so foolproof as the holder method, it may be safely asserted that the H.T.-S.T. method is now more foolproof than its predecessor. For this we have largely to thank the great advances which have been made in instrumentation and instrumental control in the last few years. Provided it is operated by a reasonably intelligent and well-trained man it is almost impossible for the modern H.T.-S.T. plant with its flow diversion valve to deliver milk which has not been adequately pasteurised. (*See* p. 553.)

Disadvantages of the H.T.-S.T. Method. Like all new ideas and equipment, the H.T.-S.T. method and the various plants which were devised to achieve it were hotly assailed in the early days of this method of treatment. As the method became better known and more dairies were equipped with H.T.-S.T. plant the volume of criticism decreased and is now confined to a very few well-defined aspects.

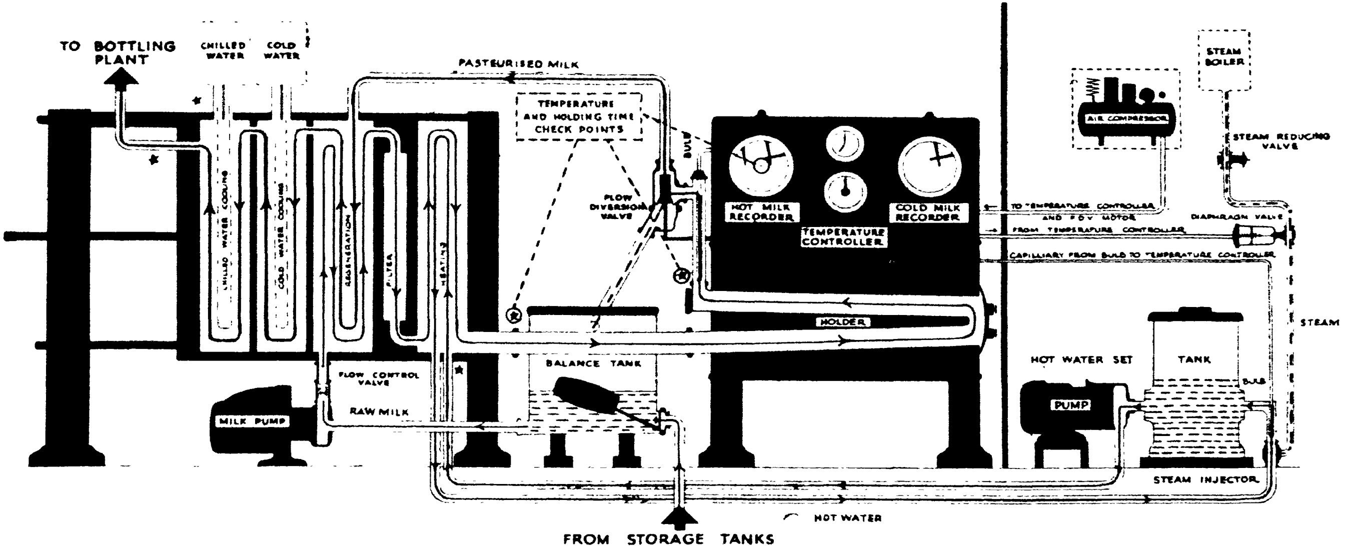
(1) Some cities have emphasized the delicate precision nature of the controls. This must be accepted as a valid criticism, but provided that operatives are properly trained and taught how to handle such precision instruments there is no reason why good results should not be obtained.

(2) On the scientific side criticisms have been made against the H.T.-S.T. process both on nutritional grounds and on the validity of the bacteriological claims for the method. Those who have attached considerable importance to the effect of heat on the nutritive value of milk have not been slow to point out that when H.T.-S.T. was first permitted there was only limited evidence as to the effect of the H.T.-S.T. process on the nutritive value of milk. However, this objection has been shown to be without foundation (*see* Nutritive value). All the arguments which have been advanced for and against pasteurisation as such apply equally to the H.T.-S.T. and the holder methods.

(3) When we come to consider the H.T.-S.T. method as a means of making milk safe we are not quite on the same sure ground as we are when assuming that its effect on the nutritive value of milk is roughly the same as with the holder method. Apart from the fact that we still have a lot to learn about the heating and cooling of milk in very short times, it will be evident that the effect on bacteria of a rapid heating and a short holding time may be different from the long-drawn-out heating and holding of the holder method.

Two factors must be considered in the heat resistance of bacteria: (i) the fundamental heat resistance of the bacterial cell when it has been definitely heated to a given temperature, and (ii) the lag effect in raising the temperature of the bacterial protoplasm to the required temperature. The latter can obviously be influenced by a variety of factors—the thickness of the cell wall, adherence of extraneous matter such as fat and protein, attachment of the bacterial cell to small pieces of tissue, etc. It may be expected that if a given bacterial cell is protected by some insulating substance such as those mentioned, then that cell will stand a better chance of surviving the H.T.-S.T. method than it will in the holder method, since with the short time method the whole heating treatment is over in about 20 sec., whereas in the holder method the corresponding time may be about ¾ hr. This reasoning applies particularly to T.B., as the tubercle bacillus is frequently embedded in small pieces of tissue in its natural condition in milk.

Much has also been written lately about the presence of heat-resistant coliform organisms in pasteurised milk, and it has been hinted that such heat-resistant coliform bacteria may more easily survive in the H.T.-S.T. process than in the holder. Very little satisfactory evidence is yet available on this point. It may



[*By courtesy of A.P.V. Ltd.*

FIG. P 3.—*Short Time Pasteurisation Flow Diagram.*

be accepted that the heat-resistant coliform bacterium is a real thing and not an artefact, but there is insufficient evidence to justify the assertion that heat-resistant coliforms may more easily survive in the H.T.-S.T. process.

Fundamental Principles of the H.T.-S.T. Method. Ideally each particle of milk should be raised instantaneously to a temperature of 161° F., maintained at this temperature for 15 sec., and instantaneously cooled to below 50° F. In practice it is impossible to achieve this. The modern plant is the best practicable compromise on the problem and succeeds in raising the temperature of the milk through the last heating stage to the required temperature in a very few seconds, *e.g.* 3 sec. Similarly, the hot milk is cooled down to a moderate temperature in the same time. It is impossible, however, to ensure a uniform heat treatment of all the milk passing through the plant irrespective of whether the heating is carried out in a plate exchanger or in a tubular holder or by the surface film method. Inevitably some of the milk passes through the heating chamber faster than the rest. The efficiency of the H.T.-S.T. plant is measured by the ratio of the time for the first milk to get through to the theoretical time by calculation from volume flow.

$$\text{Efficiency} = \frac{\text{time for first milk to pass through}}{\text{theoretical time for milk to pass through by calculation from flow}} \times 100$$

For example, supposing that 2 gal. of milk pass through a holding section of capacity 1 gal. in 1 min., it is evident that 1 gal. will pass through in 30 sec., so that the chamber will be replenished by fresh milk theoretically every 30 sec. If now it is found that some milk gets through the chamber in 25 sec., then the efficiency becomes:

$$\frac{25}{30} \times 100 = 85 \text{ per cent. approx.}$$

The modern H.T.-S.T. process usually involves five or six stages: (i) regenerative heating; (ii) heating; (iii) holding; (iv) regenerative cooling; (v) water cooling; (vi) brine or chilled water cooling.

But individual plants and at least one type of plant deviate from this general system. A schematic drawing of a modern plant is shown in Fig. P 3.

Regenerative section. Regeneration is one of the most important economic features of any heat transfer, and the modern plant achieves up to about 83 per cent. regeneration. This means, for example, that instead of 100 B.Th.U. being required for the pasteurisation of a certain volume of milk, only 17 are actually required. The saving in cost with large quantities of milk will be appreciated. Regeneration consists simply in warming up the cold incoming milk by heat transfer from the freshly pasteurised milk. Usually this will raise the temperature of the incoming milk up to about 135° F. (72 per cent. regeneration). A modern two-stage regeneration section may achieve a greater efficiency. This warm milk is then passed immediately to the heating section.

Heating section. The second or heating section is, from the plant point of view, usually identical with the regenerative section, but with hot water as the heating agent instead of hot milk. In this section the temperature of the milk is raised to 161 to 162° F. It is then passed immediately to the holding or retarding section.

Holding section. From an engineering point of view this is the most difficult of all the stages in the process, and various plants endeavour to achieve the ideal holding time of exactly 15 sec. in various ways. Plate machines originally alternated between a holding pipe and a chamber in the plant itself, but modern practice has reverted to the pipe, because such a system gives a better control of the actual time of holding the milk. Assuming that the milk has been held for 15 sec.

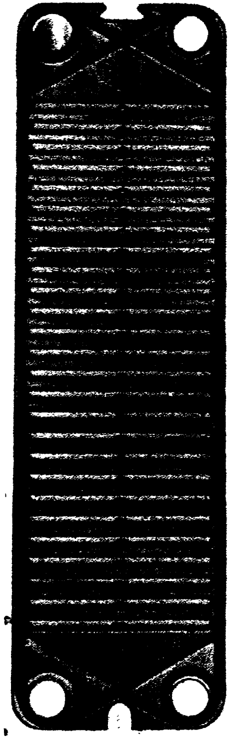


FIG. P 5.
Paraflow Type H.M.

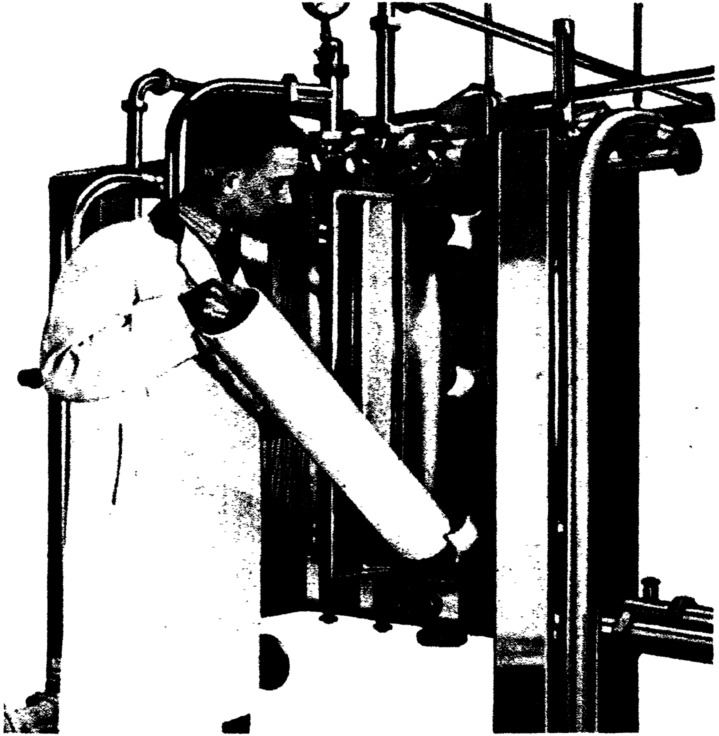


FIG. P 6.—*Paraflow Type H.M. with One Filter Open.*

[*Photos by courtesy of Aluminium Plant and Vessel Co. Ltd.*

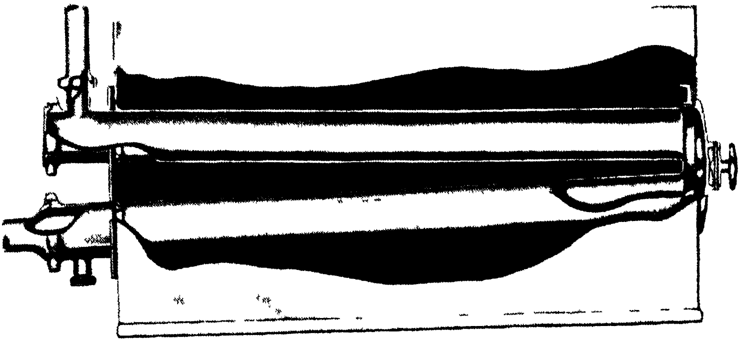


FIG P 7 —*Holder of all Stainless S T P. Plant*

[Photos by courtesy of Aluminium Plant and Vessel Co Ltd

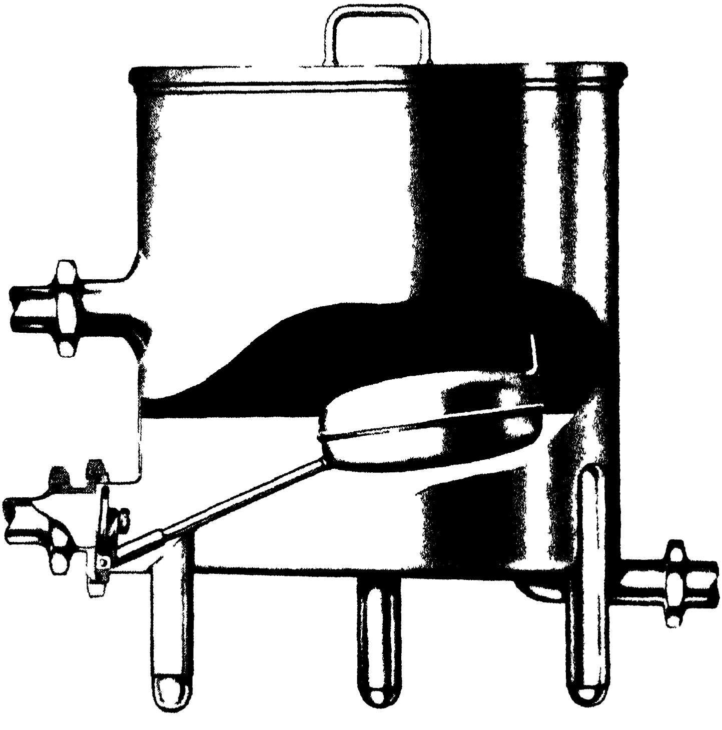


FIG. P 8.—*Balance Tank of all Stainless S T.P. Plant.*

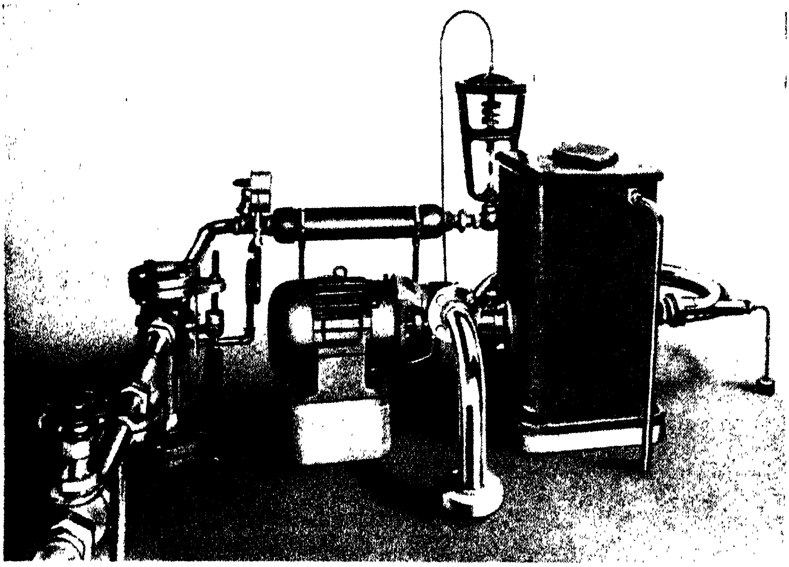


FIG. P 9.—*Hot Water Set of all Stainless S.T.P. Plant.*

[*Photos by courtesy of Aluminium Plant and Vessel Co. Ltd.*

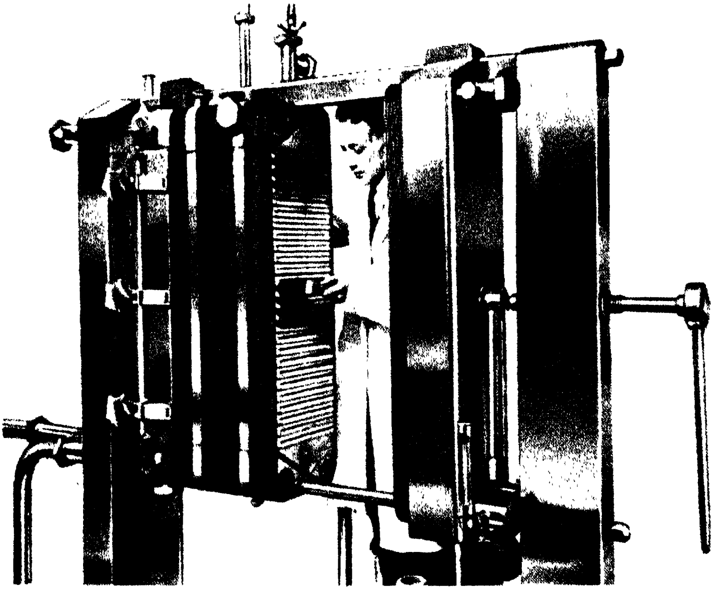
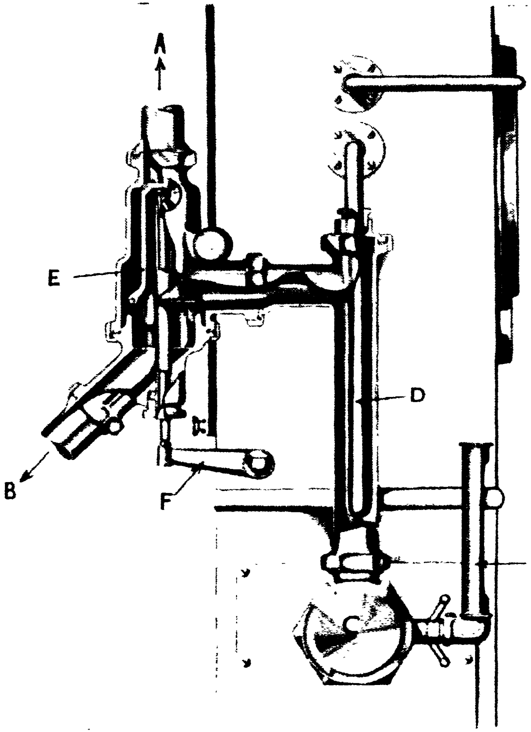


FIG. P 10.—*Paraflow Type H.M. Open for Cleaning.*



A. *To Cooling Section of Paraflow.*
B. *Diversion Pipe to Balance Tank.*
C. *Holder.*
D. *Flow Diversion Control Bulb.*
E. *Double Seated Bell Valve.*
F. *Arm Operating Valve Spindle.*
G. *Check Thermometer.*

[*Photos by courtesy of Aluminium Plant and Vessel Co. Ltd.*

FIG. P 11.—*Flow Diversion Valve.*

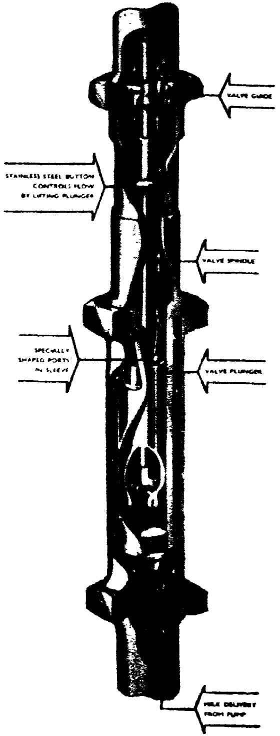

VALVE GUIDE
STAINLESS STEEL BUTTON CONTROLS FLOW BY LIFTING PLUNGER
VALVE SPINDLE
SPECIALLY SHAPED PORTS IN SLEEVE
VALVE PLUNGER
MILK DELIVERY FROM PUMP

FIG. P 12.—*Flow Control Valve of all Stainless S.T.P. Plant.*

nominal at the required temperature, the milk then passes via the flow diversion valve in the forward position immediately to the other side of the regenerative section.

Regenerative cooling. This is the inverse picture of regenerative heating, the hot milk now being cooled by the cold, incoming milk. Just as the raw milk is heated up to about 135° F. by the pasteurised milk, so the hot, pasteurised milk may be cooled down to as low as 55° F. by the incoming cold milk. The milk then usually passes immediately to the water cooling or the brine section.

Water cooling. This section continues with the cooling of the milk down from the regeneration temperature. Naturally this temperature varies considerably according to the time of the year and the source of the water supply. Mains water in summer may approach 70° F., so that one cannot get down under such circumstances to below 75° F. The milk passes immediately from this section to the last stage—the brine-cooling section. The water cooling section may be omitted from some plants, and usually is if only refrigerated milk is received.

Brine or chilled water cooling section. In this section the milk is further cooled down to *c.* 40° F. Modern practice requires that milk for retail distribution shall be cooled to and held below 43° F. There is inevitably a loss in filling out milk into bottles, so that cooling down to 38° F. is necessary in order that milk may be issued from the depot at a temperature of 40° to 42° F. The hotter the weather the colder should be the milk, but unfortunately the reverse is often the case.

The latest plants now arrange for the flow diversion mechanism to " cut off " the refrigerant in order to prevent freezing of the milk in this section.

Modern equipment has reached a very high efficiency in respect of heat exchange, and it is customary now to work with a 2° difference between the hot water and the milk. The control works through the hot water and not through the milk. In other words, if the temperature of the pasteurised milk falls the temperature of the hot water is raised. Usually no correction is applied for the temperature of raw milk. It will be obvious that there may be wide differences between the temperatures of raw milk in winter and in summer, and especially between different loads of milk, and it would be desirable to have some compensating device for the temperature of the raw milk. In addition to these causes of variation the rate of flow will also affect the rate of heat transfer, and the resultant temperature of the milk.

In the modern plant a milk film of $\frac{3}{32}$ in. is aimed at in all plates, and turbulence is attained by the special design of the plates and constrictions at certain places.

Different Types of H.T.-S.T. Plant. So far four manufacturers have plants working in this country, and these will now be considered.

(i) ***Aluminium Plant and Vessel Company.*** This is now known as the A.P.V. Co. and manufactures by far the largest number of H.T.-S.T. plants in the dairy industry in this country. The plant is essentially a plate type of heat exchanger and originally the plates were made of tinned bronze, but for some time now all plants have been made of stainless steel. A.P.V. Limited started experiments on the H.T.-S.T. process in 1923 in this country and many of their plants were in use prior to the Ministry of Health Order in 1941 permitting the H.T.-S.T. method for pasteurised milk. In such cases the milk could not be sold as " pasteurised milk ", but could be regarded as " flashed " or heat-treated in the general sense. Milk destined for manufacture, *e.g.* cheesemaking, was often treated in this way.

A.P.V. plants vary in capacity from 50 up to 4000 to 5000 gal. per hr. There are certain sizes of plant for given capacities, but these can be modified slightly by the number of plates in use. There is now a tendency to avoid the very largest sizes of plant, about 2000 g.p.h. being favoured.

A short time ago A.P.V. brought out a new type of plant, which they have termed the " Paraflow " (Fig. P 4). It is claimed that the new type of grooving on the plates gives a more efficient heat transfer (Fig. P 5). The plant is constructed entirely of stainless steel and has a continuous-acting, built-in filter (Fig. P 6). Formerly the filter sections of A.P.V. plants often consisted of a separate piece of equipment. All instruments are mounted on one panel and a double seat diversion valve is operated. A quicker response thermograph is also claimed in this type of plant. For the holding section A.P.V. have reverted to the pipe method instead of having the retarding chamber in the main body of the plant as previously (Fig. P 7).

Fig. P 8 shows the balance tank for the latest A.P.V. plant, Fig. P 9 the hot water system with steam injection valve, and Fig. P 10 shows the plates opened for cleaning.

The flow diversion valve (Fig. P 11) is of particular interest as it may be regarded as the most characteristic feature of the H.T.-S.T. plant. The flow diversion valve and temperature recorder are actuated independently by a stainless steel temperature bulb operating on an entirely new principle. This new thermometric system, developed by Negretti and Zambra in conjunction with A.P.V., undoubtedly represents one of the most important developments in milk instrumentation in recent years. Its rate of response is many times greater than that of any previous bulb and the lag is of the order of ½ sec. This enables the system to record and operate with the smallest and most rapid changes of temperature. The bulb is fitted after the holder so that it records the temperature of milk at the end of the holding period and yet will operate the flow diversion valve in time to prevent under-heated milk from passing forward to the cooling sections. The bulb is flexibly mounted on the panel and the milk fitting can be withdrawn from it for cleaning. There is no exposed capillary and so it will withstand handling without damage.

Several notable improvements are incorporated in the new design A.P.V. flow diversion valve. This valve positively and automatically diverts the flow of milk should the temperature fall below the legal limit and automatically passes the milk forward again when the correct temperature is regained. It is simple and robust and, being made entirely of stainless steel, is very easy to clean. The method of operation is by air pressure working against a strong spring, so that should the temperature fall a very small plate operated by the thermometer bulb releases the air pressure and the valve closes immediately. When the temperature is regained, air pressure builds up and the valve opens to the forward flow. The system is arranged so that any failure of air or electricity moves the valves into the " diverted " position. A green light on the panel indicates that the air and electrical circuits are in order, and on diversion a red light shows and at the same time a warning bell rings. Fig. P 12 illustrates the flow control valve.

Fig. P 13 shows the type of A.P.V. plant very common in this country.

(ii) ***Clarke-Built*** (formerly Cherry-Burrell). This company has recently introduced an H.T.-S.T. plant to this country which is constructed broadly on the same principles as the A.P.V., but it is claimed that it has certain advantages and an improved type of flow diversion valve. As with the latest A.P.V. model, the holding section consists of an external pipe (Figs. P 14 and 15).

(iii) ***Creamery Package.*** The latest design includes a rubber " plate " which permits a smooth carrier plate to be used (Fig. P 16*a*). The complete plant is illustrated in Fig. 16 *b*.

(iv) ***Graham Enock.*** This firm has evolved two types of H.T.-S.T. plant. Whereas the three types mentioned above are basically the same, employing the plate type of heat exchanger pioneered by A.P.V. Limited, the first Graham Enock is of quite different design and appearance, and may be considered to have evolved from the old " Gem " unifier plant for pasteurising milk by the holder process. The Graham Enock plant consists of wings, each capable of treating 220 gal. of milk per hr. (Fig. P 17). To enlarge the plant, therefore, merely involves the addition of more wings. The cold incoming milk is first passed through the *inside* of the regenerative section and from this passes to the top of the wing. It is now allowed to fall down the outside of the top heating section through the interior of which hot water flows. The milk attains a temperature of the required degree at the bottom of this top heating section, and is then collected in a trough, from which it passes across the width of the wing through a holding trough which has been so designed as to give the necessary holding time of 15 sec. From this trough it passes past the temperature bulb to a distributing trough over the water-cooling section. The refrigeration section is continuous with and immediately below the cold water section, and consists of a direct expansion cooling unit. It will be evident that the Graham Enock design is fundamentally different from the other three, and the outstanding points of interest are the use of the surface film for attaining quick heat exchange, the trough for holding and the direct expansion unit for cooling. In addition a novel and very simple but effective type of flow diversion is used. Instead of a valve being lifted from its seat inside a pipe, which is the principle used in other plants, in the Graham Enock, when diversion occurs, the arm projecting from the control panel tips over a collecting bowl at the end of the trough, which then passes the milk back for another heat treatment (Figs. P 18 and 19). The reaction is very delicate and extremely rapid. Many companies have found the Graham Enock plant capable of giving excellent results, but it will be obvious, from its design, that it is liable to different sorts of errors from other plants. Possibly the most important difference from the point of view of any tendency to faulty behaviour is the fact that each wing in the Graham Enock plant is essentially a plant in itself, whereas in the other plate type of heat exchangers, no matter what size the plant, the plant can only behave as one unit, as all the milk is common and is passed through the same chambers, pipes, etc. In the Graham Enock, however, there is a distribution of milk over the wings—for example, in a 1100 gal. plant, milk at the beginning of its treatment is split up between five separate wings and each wing can behave independently if allowed to do so. As the outer wings are exposed to the cooling effect of atmospheric air, it is only to be expected that the temperature of the milk on these wings will be somewhat lower than that inside. It is essential, therefore, to have insulating shields protecting the outer wings of a multi-wing plant. Assuming that this is done and that the temperature control of the water and the flow of water and milk are constant, there is no reason why a multi-wing plant should not give good results, but any unevenness in operation between the wings may easily lead to a faulty product. The latest models have special control apparatus for the outer wings, and all wings now feed into a common trough.

The surface film principle of the Graham Enock plant allows it to claim some advantages over the plate type of exchanger. Thus the gravity flow principle gives a far more gentle treatment to the milk than the highly turbulent flow of the plate machine, and consequently it is claimed that the cream line of milk pasteurised by this method is superior to that obtained from any other type of plant. In addition, the exposure of the milk in passing over the wing enables any undesirable odours to pass away from the milk.

" Gem " Unified Short Time Pasteuriser. This company has recently introduced a plate-type of H.T.-S.T. plant (Fig. P 20).

Throughout the installation the milk piping and fittings, all in stainless steel, are so designed that all surfaces can be seen by looking through the fittings or down the pipes. Standard bends are used wherever practicable. The positive milk pump is of stainless steel throughout. The pump contains two rotors, one working within the other so arranged that there is no direct contact between them. Therefore there is no tendency to wear, which would otherwise reduce efficiency. The rotors are actuated through a gear box containing a reduction gear which reduces the speed from motor speed of 940 r.p.m. down to rotor speed of 300 r.p.m. The gears and all parts of the mechanism run in oil; stainless steel heavy duty shafts are fitted and carried by heavy duty ball and roller races. The pump is made in two sizes to operate from 600 gal. per hr. up to 1200 gal. per hr. and the larger one 1250 gal. per hr. up to 2500 gal. per hr. These pumps are of the positive type, and into the operating gear is fitted a tachometer, the dial of which is of waterproof construction and indicates the gal. per hr. of milk at which the pump is operated.

The milk enters the filters at the front of the plant, *i.e.* at the back end of the filters, and passes first through a stainless steel woven mesh gauze strainer of 6 in. diameter by 2 ft. 6 in. long which takes out all the " rough " matter. After this the milk passes through the secondary stage of filter cloth which is supported inside a stainless steel perforated tube about 7 in. diameter × 2 ft. 6 in. long. There is an inlet valve to each filter inside the branches to the filters at the front of the machine. These valves are hand-operated. Each filter has an outlet valve which is automatic in operation, and when the filter inlet valves have been closed, and as the milk is being drained into the hopper, the back pressure of milk from the heater section closes the outlet valves to the filters. Both sets of valves are easily removable for cleaning and the valve seats are fitted with removable rings similar to those used on the float in the hopper and in the diverter valve.

In this plant under average conditions and duties the pressures would be as follows:

	lb. per sq. in.
Milk	10
Hot water circulation	17
Mains water	3 to 10
Ice water circulation	16

Heat exchanger plates. These are made from 20 gauge stainless steel. When the rubber gaskets have been fitted into the plates and the plates are compressed in the heat exchanger itself, the centres, plate to plate, during the average life of the rubber is just under 0·2 in., *i.e.* 5 plates to the inch. The plates are made left and right hand to enable diamond-shaped passages to be formed between the plates which will permit the maximum turbulence of the milk during its passage through the plates. The gasket inside the plate is made of special tough rubber and formed of a one piece moulding fixed into the plate by a special adhesive solution which is easily applied.

Flow of milk. Raw milk enters the float hopper, and is drawn out by the milk pump, which delivers to the bottom right-hand corner of the holder unit, where it enters the regenerative section. After regeneration the milk passes into the holder unit and is carried by a stainless steel pipe along the top right-hand side of the holder unit, emerging at the front right-hand corner and passes downwards, branching to each of the filters. The hand-operated valves to the filters are placed in the branch pipes at this point. After passing through the filters and the outlet valves in the branch to each filter, the milk goes to the heater section *via* a connection in the bottom of the back of the holder unit. The outlet from the heater passes directly into the holder proper at the front, left-hand top corner of the holder unit, and each size holder has an odd number of tubes—that is, 3 for 500, 5 for 1000, 7 for 1500, and 9 for 2000 gal. per hr., this arrangement enabling the outlet of the holder (the diverter valve) always to be placed in the same position and at the back of the unit. In the 2000 gal. per hr. holder, the milk travels 9 × 27 ft. When facing the back of the unit, diverted milk passes to the right and into the float hopper. When operating normally, however, milk passes to the left and into the bottom left-hand corner of the back of the holder unit, from which it directly enters the regenerative section, again emerging from it at the front of the machine at the top intermediate division plate, and then passes direct into the mains water section at this point. The milk leaves the mains water section at the bottom of the back of the unit, and this point also feeds the milk to the ice water section. Finally, the milk emerges at the front of the machine at the extreme top right-hand corner *via* the special cleaning tee, which contains the cold milk thermometer bulb and a tapped boss for an indicating thermometer.

Pneumatic opening and closing plates. The whole of the weight of the plates and followers is carried on a slideable top bar passing right through the machine. A cylinder is formed where this bar passes through the holder compartment, and a piston is mounted on the carrying bar and, by the admission of air to one side or other of the piston, the whole of the plates and followers can be moved to the " open " or " closed " position. The plates are finally clamped up most of the way by the stainless steel 12 in. diameter hand-wheel, being finished off with the ratchet spanner placed over the nut which forms the boss of the hand-wheel.

Holder tubes. As mentioned previously, the number of tubes is increased for the capacity of the plant, these being of approximately 3 in. in diameter. If any particular capacity outside 500, 1000, 1500 and 2000 gal. per hr. is required, the next side holder is called for and a displacement piece or pieces put into one or more of the tubes to obtain the exact capacity. The holder tubes are surrounded by hot air. This hot air pocket round the holder tubes has the advantage of maintaining a steady temperature in the holders. This should result in an improved creamline. The diverter valve is double-acting with a removable rubber seat on each valve so that when the milk diverts, not only is the outlet to the milk heater opened but the outlet to the regenerative section is closed. The operation of the diverter valve is by air from the diaphragm valve situated in the instrument compartment similar to that employed on the film type H.T.-S.T. The hot milk bulb is arranged with a rigid fixing so that the diverter valve may be removed entirely from it, leaving the bulb permanently in its position.

Instrumentation. The latest model " Foxboro " instrumentation with dual temperature control is employed, the instrument on the machine being actuated by the milk bulb, and a separate instrument mounted adjacent to the hot water circulating set controls the water. The instrument on the unit is of the two-pen type, with special charts which emphasise the importance of 161° F. for pasteurising temperature, and 40° F. for cooling temperature. The extent and duration of diversion is also recorded on the chart. The cold milk bulb is also of the rigid stem type, and can be turned through a right angle when the press is opened for cleaning; alternatively, if it is required to open the press without removing the cold milk bulb from its attachment to the press, this can be done with safety, as there is a large amount of travel horizontally permissible on the rod leading up to the bulb. In fact, the same rod and bulb are used whether the press is fitted with plates for 500 or 2000 gal. per hr. The instrument chamber is accessible from the removable top lid which slides backwards off the unit, and it is very easy to remove the instrument with its bulbs completely from the unit. The instrument chamber also contains the air motor, strainer, air condenser vessel, reducing valve, hot-water connections, air and electrical connections and air cylinder for opening and closing the plates. The instrument chamber is fitted with two drain pipes in the bottom, which will prevent any condensation or water lying in the chamber. These vent pipes pass down through the holder chamber and deliver any condensate out on to the floor below. To ensure that no water, either from this condensate or from any hosing, might find its way into the milk hopper underneath, a fixed stainless cover is provided in the base of the machine which protects the hopper when placed in its operating position.

Hot-water set. The heating medium is provided by means of a hot-water circulating unit comprising hot-water tank and pump, the latter arranged for a ratio 6 : 1 hot water to milk, *e.g.* 6000 gal. per hr. hot water 1000 gal. per hr. milk. Steam injection is provided through a mixing tee, and is fitted in the hot-water return pipe to the tank.

Air compressor. This unit produces the necessary compressed air for operating the temperature controls, diverter valve and air for opening and closing the machine. The unit comprises a cylindrical reservoir 3 ft. 3 in. long × 1 ft. 4 in. diameter, arranged to maintain air at 60 lb. per sq. in. The compressor is mounted on top of this cylinder producing 2·8 cu. ft. of air per min. It is fitted with an automatic electrical switch arranged to cut out at 60 lb. per sq. in. The air supply to the temperature controls passes through a fine filter and moisture trap.

The Gem KV Type Chilled-Water Unit (Fig. P 21) has been designed to cool and circulate water at 35° F. through the final cooling section of the GEM unified short time pasteuriser.

The unit is constructed to house a series of metal-sprayed rust-proof evaporators of corrugated form. The number of evaporators depends upon the total cooling capacity required. The operation is dependent upon a fully flooded ammonia system with positive refrigerant control and constant evaporator temperature to ensure a constant chilled water temperature.

(*v*) ***Alfa-Laval.*** The Alfa-Laval H.T.-S.T. plant is manufactured by A.B. Separator in Sweden. The heavy stainless steel plates are profiled to gain maximum turbulence of the milk without sacrificing cleaning facilities, and permit high internal pressures to be withstood. The plates have a large projected surface area made possible by the principle of extreme rigidity, thus reducing the number of plates for a given duty to a minimum. Standard regenerative sections of 85 per cent. heat recovery are normally supplied. The machine is also available with a holding section, forming part of the plate pack assembly, or alternatively with a separate air-insulated holding tube for which efficiencies exceeding 90 per cent. are claimed.

One of the most interesting features of the heat exchanger is the adoption of vacuum steam heating as an alternative to the conventional hot-water method. The former method of heating is made possible by plate design and the ability to withstand internal vacua. The principle consists of reducing the internal pressure of the heating channels initially by means of an ejector pump, to approximately 28 in. vacuum. The reduction in pressure is, through the medium of vacuum relay, transmitted to the diaphragm of a steam valve which directly compensates the pressure fall by allowing steam to enter the heating section. The relay is adjusted to ensure maintenance of approximately 19 in. vacuum or a steam-condensing temperature approaching 163° F. In this manner a temperature difference comparable with water heating is readily obtainable with the application of direct steam and for certain conditions is claimed to be less than for the former medium. The multiple ejector system driven by a single motor also enables independent vacua to be available as servo media for operating the control valve and flow diversion valve for sub-temperature milk, thus completely eliminating the use of compressors.

The close limit milk flow control valve is of robust easily-cleaned construction from which it is claimed that hammer is completely eliminated.

The milk flow balance tank is of minimum capacity to ensure quick temperature recovery after diversion and a minimum period of excess temperature subsequent to automatic forward flow.

In other respects the Alfa-Laval system is similar to equipment of other manufacturers, both as regards instrumentation with high response rate, fully automatic diversion control, and temperature recording both of the milk leaving the holding section and the final chilled water or brine section. The instruments and controls are centralised without exposed capillaries on a water-tight stainless steel panel of small dimensions to which the flow diversion valve is also attached.

Fig. P 22 shows a typical installation in which the vacuum operated steam valve and control panel are clearly visible. The holding section in this particular case is an integral part of the heat exchanger.

(vi) ***Silkeborg.*** Another well-known continental make is illustrated in Figs. P 23 and P 24.

American Experience of H.T.-S.T. Pasteurisation. It is naturally of considerable interest to obtain the reaction of American experts to the H.T.-S.T. method. R. J. Winning (Milk Industry Foundation, *Bulletin*, U.S.A., 14 February, 1947) has summarised the advantages and disadvantages as follows :

" ***Advantages.*** (1) With the automatic control and flow diversion valve installation which is in common usage now, it provides a double safety standard and practically eliminates the possibility of unheated milk passing through the pasteurising unit.

(2) With the automatic controls, the operation of the short-time unit is more tamper-proof in that milk is not exposed as it is in open type equipment which always presented possibility for contamination from condensate, etc.

(3) With a calibrated milk-holding tube, the holding time is not subject to variation and more constant operation results.

(4) In plants of medium and larger size, the initial cost of the equipment is lower. This probably does not hold true in smaller plants or in places where many different products are pasteurised and where tanks are still needed for the final processing, *i.e.* buttermilk and sour cream.

(5) There is a tremendous saving in floor space which is a very valuable asset in larger plant operations. One operator reports that it was possible to save approximately 30 per cent. of his processing area when he converted from long-flow holders to short-time plate type equipment.

(6) In starting operations, under long-time pasteurising system, it was necessary to start up the equipment approximately 35 to 40 min. in advance of the filling schedule. With short-time pasteurisation, it is possible to eliminate at least 30 min. of this advanced operation which provides a greater flexibility in operations and enables one to tie in the pasteurising and bottle-filling operations.

(7) With the exception of first milk through the unit, which must be by-passed until forward flow is obtained through the flow diversion valve, full regeneration is obtained during the entire period of operation, whereas on long-flow systems the first 30 min. and the last 30 min. are without regeneration.

(8) Consistent with the reduction of the number of pieces of equipment required for any given pasteurising capacity, there is a considerable reduction in the man-hours of labour necessary to clean and sterilise the pasteurising equipment.

(9) With the use of automatic controls and with a relatively short training period, an operator can become quite proficient in the operation of plate type equipment and, we believe, the equipment is easier to operate than the more bulky long-time holding systems.

(10) The use of completely automatic control systems ensures a uniform operation from day to day and tends to make for a more uniform high-quality finished product.

(11) The use of higher heating temperatures would tend towards the elimination of thermophilic type organisms.

(12) Plant expansion can be accomplished, and increases in pasteurising capacity can be made at rather nominal cost by simply adding plates to existing frames and by changing the length of the holding tube.

(13) If operational difficulties make it necessary to shut down, there is less milk overheld than there would be in the long-time holding system which again tends to improve the finished-product quality, particularly with respect to cooked flavour and creamline damage.

(14) Where a complete plate type short-time unit is used, the milk is handled entirely in a closed system which has many advantages, one of which is that it eliminates the necessity of pumping the finished product after pasteurisation which again assumes some importance in the production of good creamline on milk.

(15) The use of less pasteurising equipment tends to minimise product losses in the plant, particularly where new plants are being designed. It is easily possible to make a close coupled operation which holds milk losses to a minimum.

(16) While the question of the relative killing-power on non-pathogenic organisms is somewhat a debatable issue, it appears as though with a good quality raw milk supply it is possible to do equally as good a job on short-time as on the long-time holding method. However, there appears to be a tendency toward higher counts on milk which may have some thermoduric type organisms present where this milk is pasteurised on short-time as against long-time. This can be viewed as a disadvantage of the plate type equipment but, in the final analysis, we should be interested in the maintenance of higher quality raw milk products and the elimination of the thermoduric organisms from the raw milk supply.

(17) By keeping the milk under pressure during the entire heating, holding, and cooling operation, there appears to be less tendency toward foaming and, from a practical view-point, this means a better control over the filling point in the bottles. By the same token, it is easier to sterilise short-time equipment because it is possible to reach the milk surfaces with sterilising solutions or hot water by simply pumping the solution through the pasteurising equipment; whereas on long-time pasteurising systems, it is necessary to spray the covers and other portions of the tank—with which the milk does not actually come in contact—but which may be a factor in proper sterilising due to the precipitation of moisture that may drop from the air into the milk and be a factor in the contamination of the finished product.

The foregoing list of advantages for short-time pasteurisation from a practical viewpoint would seem to outweigh the disadvantages of the process, but, in all fairness, it should be recognised that there are many things which are in need of further attention before the process can be considered completely acceptable to the industry.

Disadvantages. The following disadvantages at the moment have presented themselves in the consideration of short-time high temperature pasteurisation :

(1) One of the most objectionable items in the consideration of the use of plate type short-time pasteurisation is the fact that the seal between plates is effected through the use of rubber gaskets which, generally speaking, are mounted in gasket grooves. The methods used for the application of these gaskets to the plates vary from the use of a so-called " cold process " in which a rubber cement is applied to a previously cleaned gasket groove, and the gasket is laid in place and pressed in the groove without any application of heat. Other manufacturers have developed a method of so-called " vulcanising " the gasket in the groove and attaching it with this cement. In this process, however, the unit is assembled and hot water is circulated through all of the plates, usually at temperatures around 180° F. for 30 min., which treatment has the effect of " vulcanising " the gasket to the plate. One manufacturer does not make use of a gasket groove but not too much experience has been obtained in the use of this unit on a large commercial basis. Therefore we are not in a position to evaluate this latter method.

The gaskets themselves are made of a rather hard rubber and in themselves do not appear to be any factor from the standpoint of sanitation. However, in practical plant practice it has been observed that there exists a tendency for these gaskets to become disengaged from the gasket groove and, of course, open seams result, which are undesirable from the sanitary standpoint. It is pretty generally accepted, however, that complete sterilisation can be secured even when some fractures occur in the bond between the gasket and the plate. The majority of equipment companies are quite aware of this problem and recognise it as being one which must be completely solved before the process of short-time pasteurisation using plate-type equipment will be acceptable on a nation-wide basis. A great deal of research of practical plant trials has been responsible for a considerable improvement in the methods of attaching these gaskets, but the latest developments have not as yet had sufficient trial in the field to warrant a statement as to whether or not they are satisfactory.

In addition to posing the problem from the sanitary viewpoint, the use of gaskets which are apt to loosen from the plate presents a practical plant-operating problem, especially where the pressure is rather high inside the plates. With a loose gasket there is a tendency, when the unit is assembled, for this gasket to squeeze out of the gasket groove which takes away some of its resistance to the internal pressure and may cause a blowout of the gasket during operation. When this occurs, it is necessary completely to dissemble the unit, replace the gasket, reclean and resterilise the unit before starting up again. It is generally felt that there is considerable room for improvement in this respect and it is to be hoped that further research and experimentation will result in this improvement.

(2) Another factor which should be carefully considered by plant operators in choosing a pasteurising system is to be sure that attention is given to the needs of the particular operation for which the equipment is being purchased. In certain types of plant operations, particularly smaller plants, the advantages in the use of short-time equipment are not so apparent as they are in larger dairies, particularly where a smaller dairy wants to use the pasteurising system for the processing of several different grades of cream and in the production of buttermilk, sour cream and other speciality products, which, at the moment, have not been worked out too satisfactorily on short-time equipment.

(3) In discussing the advantages of plate type short-time equipment, the factor of operating a closed sytem was emphasised. It should be pointed out that in the use of this type of pasteurising equipment where a cooling medium is used at a temperature below the freezing-point of milk, provisions must be made to ensure against the freezing of the milk in the plates in the event of a shut down. If this occurs, the danger is present of starting up a positive pump and trying to force milk through the unit when the milk flow ports may be frozen solid.

(4) Further work must be done on control mechanisms to further improve the methods of operation. Some improvement can be made in the construction of, for instance, the flow diversion valve. From a practical standpoint, it would seem that we should have a stainless steel body in flow diversion valves. The use of white metal bodies does not appear practical because the valve stems wear and the valve body itself is subject to pitting, either due to some electrolytic action or to the use of acid type cleaners.

Further, with the present construction of some of these valves, it is possible to put the valve in the valve housing in an upside-down position and yet the unit will operate.

Operating Suggestions for the Use of Plate Type Short-time Equipment. (1) Where the milk leaves the cooling section of the short-time unit, it is sometimes the practice to keep the milk under pump pressure and pump it to a tank which is situated on a level lower than the short-time unit. In such cases, the possibility of siphoning does exist during a shut down. This is easily corrected by installing a vacuum breaker on the discharge line from the short-time unit.

(2) In setting up a new unit and in calibrating the holding time, it should be remembered that the flow of milk should be timed both in forward flow and diverted position. Usually, the diverted milk line is shorter than the forward flow holding tube and, therefore, when a unit returns to forward flow after a diversion, there is the possibility that some of the milk first going through the holding tube would be slightly underheld. Increased time in the diverted position is easily obtained by means of an orifice plate which can be inserted in the diversion line from the short-time unit.

(3) The cleaning operation is greatly facilitated if the unit is completely airtight. The entrance of air into the milk and the probable release of this air while the milk is being sucked through the raw milk side of the regenerator, apparently

increased the tendency of milk solids to build up on the regenerative plates. It should always be remembered that in the final heating section and in the cooling section, there is not too great a temperature differential between the heating and cooling media and the milk being heated or cooled, whereas in the regenerator section there is a temperature differential between hot pasteurised milk at 161½° and preheated milk leaving the regenerator at a temperature of approximately 135°. " Scale " can be materially reduced if the vacuum can be reduced in the raw milk side of the regenerator. To do this, and still comply with the public health requirements for maintaining greater pressure on the pasteurised milk,[1] means that you must start up the unit on the conventional suction method. Once forward flow has been obtained, however, a small centrifugal pump in the line leading to the raw milk regenerator and properly calibrated so that zero lb. pressure results at the suction side of the timing pump will considerably reduce the amount of " scale " on the raw milk side of the regenerator. This installation can be made automatic by connecting this centrifugal pump to the flow diversion valve so that when the valve goes into forward flow position, the pump will turn on.

(4) Practical operation of the short-time unit in connection with homogenised milk is made simpler by the use of a by-pass arrangement so as to permit a change to homogenised milk without shutting down the unit. This also can be arranged through the use of a small balance tank between the timing pump and the suction side of the homogeniser. Where homogenised milk is processed and where homogenising is required before pasteurisation, it is the general practice to use homogenisers as timing pumps. Therefore the holding tube should be calibrated and checked with both homogenised milk and regular milk.

(5) In running homogenised milk, it has become quite a common practice to run at a higher temperature than that normally used on a creamline product. Temperatures used vary from approximately 165° to as high as 175°, and have no harmful effect on the finished product. This is an important factor in that a greater reduction of bacterial count is experienced on the use of these higher temperatures. Of course final cooling is affected and provision must be made for additional surface to obtain satisfactory cooling at higher temperatures of operation.

(6) In the cleaning operation some companies have found it to their advantage to recirculate acid-type cleaners, followed by an alkaline rinse before dissembling the unit for hand-scrubbing. In many cases a cleaning tank with a suitable outlet is used for the make-up of the acid cleaning solution to be recirculated through the unit, and sanitary pipe lines can be placed in this tank which makes the cleaning of sanitary lines an easier task."

Operation of Pasteurising Plant. This may conveniently be considered under the following headings: (*a*) Starting; (*b*) Running; (*c*) Finishing or shutting down; (*d*) General maintenance.

Naturally the three basic types of pasteuriser—the Batch, the Holder and the H.T.-S.T.—will differ considerably in their operation. Broadly speaking, the Holder plant may be regarded as intermediate between the Batch and the H.T.-S.T.

The Batch Type Pasteurisers. From the constructional point of view these are the simplest of the three types, but it is possible to get poor quality pasteurised milk because the Batch method has certain well-recognised faults. Probably the most common causes of poor keeping quality in Batch pasteurised milk are: (1) The formation of foam on the top of the milk. (2) Forward leakage. The latter is especially treacherous if two or more holders are connected to a common outlet.

Obviously the first requirement when starting a Batch type plant is to ensure that all the surfaces of the equipment are perfectly clean (*see* p. 246) and that the

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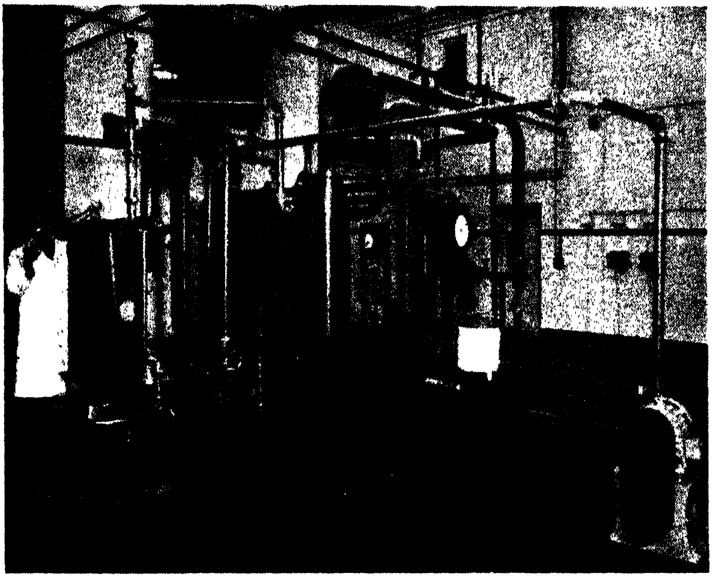
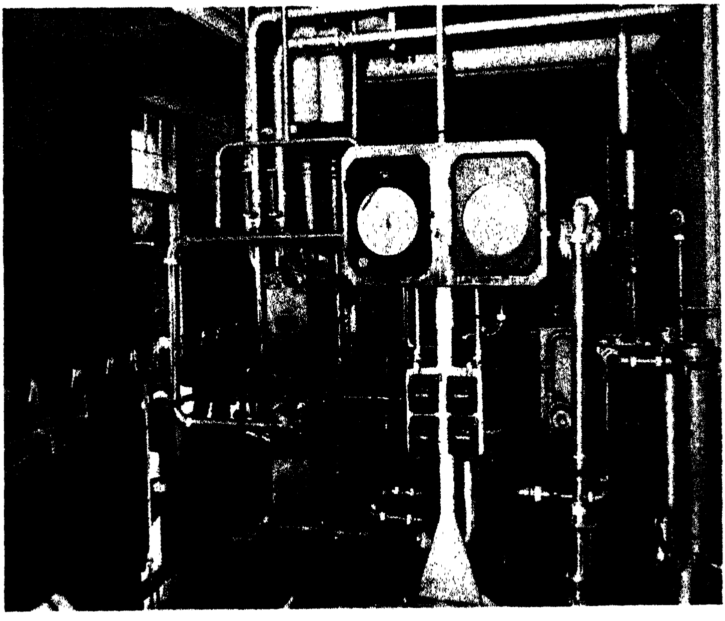
[1] In U S.A.



[*By courtesy of Aluminium Plant and Vessel Co. Ltd.*

FIG. P 13.—*Complete H.T.-S.T. Plant in Dairy.*



[*By courtesy of Clarke-Built Ltd*

FIG. P 14.—*200 g.p.h. Cherry-Burrell H.T.-S.T.* Plant.

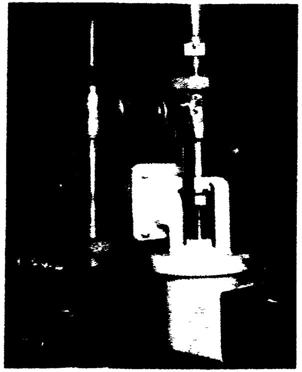
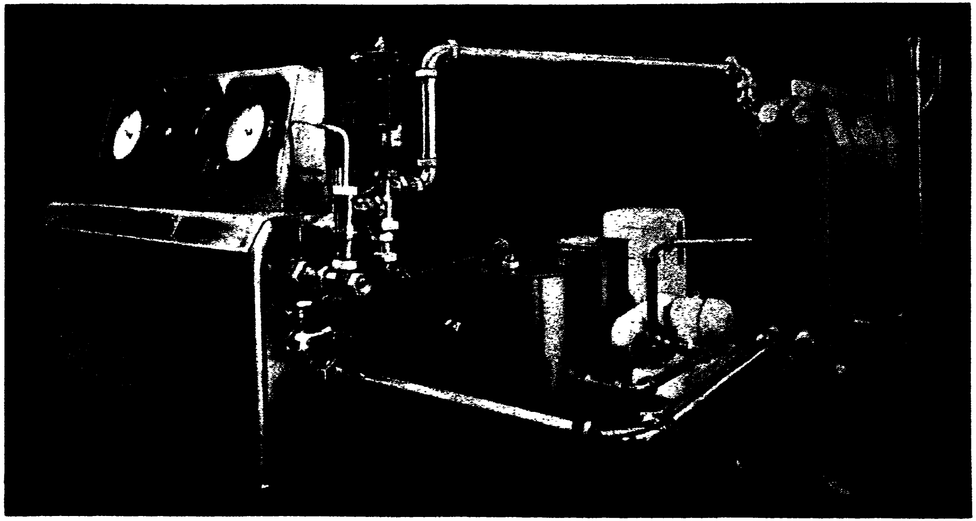


FIG. P 15 (*a*).—*New-Type Flow Diversion Valve, mounted in position on the new combined Cherry-Burrell Control Panel and Holding Tube Cabinet.*



[*By courtesy of Clarke-Built Ltd.*

FIG. P 15 (*b*).—*Cherry-Burrell H.T.-S.T. Plant* (500-2000 *g.p.h.*).

parts of equipment are correctly assembled and the thermometers in position. The recording thermometers should be set accurately so that the pen records the same temperature as that shown by the mercury-in-glass thermometer. The recorder should have an ample supply of ink and the mechanism, if clockwork, should be fully wound. The outlet valve is then shut and care taken that there is ample water in the outer jacket. Heating may be carried out by live steam, and then it must be seen that the reducing valve is working properly and that the fan at the top of the jacket is open. When steam is admitted the trap should be watched to see that it is functioning correctly. After a short time a slight pressure will be built up in the jacket, which will be noted on the gauge, and the air valve should be closed when vapour is issuing from it. It is desirable to keep the temperature difference between the heating water in the outer jacket and the milk in the pasteuriser as small as possible in order to minimise the deposition of the calcium salts from the milk on the surface of the holding vessel. When the holding temperature (145° to 150° F.) is attained, the steam valve should be regulated so as to maintain the milk at this temperature. Usually very little steam is required from this stage onwards.

Automatic controls are now being used for Batch type pasteurisers and these, when present, should be most carefully inspected to see that the valves are really opening and shutting at the correct times and temperatures. It is essential that during the whole of the thirty minutes holding period the temperature of the milk does not fall below 145° F. After this time the outlet valve is opened and the milk then flows direct to the cooler either by gravity or by pumping. Cold water may be admitted to the jacket at the same time.

Holder Pasteurisers. This plant differs from the Batch in that the heating and cooling take place outside the actual holding vessel. In modern types of holding plant, the heating and cooling are virtually identical with that used in the H.T.-S.T. plant. Holder plants are invariably of greater size than Batch plants, which usually have an upper limit of about 100 gal. per batch holder.

In starting the Holder type of plant all ancillary equipment should be checked to ensure that it is functioning properly. The hot water and brine (or chilled water) must be at the right temperatures and ample steam pressure should be available. All parts of the equipment must have been cleaned and sterilised (*see* p. 246), and the whole plant re-assembled correctly. All joints should be tight and clean, and sterile filter cloths properly fitted. Pumps must be working correctly.

If the Holder compartments have hot-water jackets these should be warmed up and the thermostatic control checked. Milk is then allowed to flow into the dump tank and the correct valves opened.

The cooling water and secondary refrigerant should be started just before the milk from the first holder is due to leave. A check should be made that the balance tank valves are in the correct position to allow the flow of milk to the bottling plant.

H.T.-S.T. Plant. It is customary for the entire plant to be stripped and cleaned over-night and then re-assembled and sterilised by hot water or chlorine solution (*see* p. 255) immediately before use. Care should be taken that the sterilising solution is properly drained from the plant. This operation takes place with the heat exchanger plates slackened off and the plates are then tightened and all drain plugs opened to give complete drainage. Milk pipes should also be slackened or momentarily opened to ensure that no water remains at the lowest points. After checking the hot water set, cold water (if used) and brine or chilled water, and that the filter cloths are properly fitted and the flow diversion valve open, the milk pump is then started and as milk pushes through the remaining small quantity of water, the vents are closed in turn. It is good practice always to collect the first few gallons issuing from the plant (the exact volume will naturally depend on the size of the plant) in a churn and provided it is free from added water, this may be returned to the hopper. The advantage of this is that not only will the traces of water left be more evenly distributed, but the residual bacteria in the plant will be killed by the re-pasteurisation process.

All instruments should have been checked in the usual way (*see* p. 546) and the exact temperature of flow diversion should be checked as early as possible. In practice this would have been done automatically during the sterilising and preparation of the plant for the milk.

The frequency with which the filter cloths are changed can only be learned by experience and will naturally vary with the quality of the incoming milk. Pasteurisers usually know fairly accurately the quality of their raw milk, and there is much to be said for standardisation of changing filter cloths, *e.g.* every 20 min. or 30 min., etc. The milk pump pressure gives a good indication of the rate at which the filter cloth is becoming clogged. Blocking of the filter will naturally slow down the rate and by the increase in holding time will have a deleterious effect on the cream layer of the final product. To obtain the highest quality of pasteurised milk, filter cloths should be most thoroughly washed and properly sterilised before re-use.

Control during Running. Provided a well-designed plant is used, and is carefully looked after and well maintained, and the pasteuriser is in attendance the whole time and has the vital parts of the plant under his observation, there should be no troubles arising during the actual running of the plant.

Shutting Down. ***Batch pasteuriser***, This is quite a simple part of the operation and the most important thing is to see that a thorough flushing through the plant with water is given before the milk has time to form a firmly adhering film; in this way subsequent cleaning and sterilising operations are greatly facilitated. Pipe lines, pumps, coolers, hoppers, etc., should be dismantled as soon as possible and very thoroughly washed down and preparations made for cleaning.

Holder and H.T.-S.T. Plants. The shutting down operations for both these types of plant are very similar, and the procedure may be put into operation, not only at the end of the completed day's run, but also at some intermediate point. As a result of much experience, it is considered good practice not to run a Holder or H.T.-S.T. for longer than a certain period, *e.g.* 4 or 5 hr. The reason for this is that heated milk, and especially milk which is being heated as in the actual heating section itself, may deposit calcium salts on the surface of the plant, and thus lead to the formation of milk stone which can be a cause of prolific growth of certain types of bacteria, namely the thermophilic types (*see* p. 1022) which can grow at Holder pasteurising temperature. Although the H.T.-S.T. process heats milk at 161° F., in certain parts of the plant the temperature of the milk is in the range of 100° to 145° F., which affords most favourable conditions for the growth of these types of bacteria. Trouble from this cause with a well-managed H.T.-S.T. plant is now very rare, but Holder plants are particularly susceptible to the growth of thermophiles on account of the somewhat lower temperature (145° to 150° F.) and occasions have been known where the whole volume of milk in a holding compartment has become solid and has literally had to be dug out. A break in the run is, therefore, essential for the Holder type of plant and is strongly recommended for the H.T.-S.T. plant. In principle, the same procedure is used. The milk must be drained as efficiently as possible from all parts of the plants, and the common method is to push through the last milk with water. A vital point in this procedure is to know the exact point at which the milk changes to water at the cock which controls the forward flow of milk to the finished milk tank. This can be calculated by knowing the total volume of milk in the plant and the rate of flow. Useful information can also be obtained by the use of an instrument designed to indicate the proportions of water and milk in a mixture of the two (Davis (In press)). It is naturally always wise to change the cock very slightly before this point is reached, in order that there is no danger of water getting through to the finished

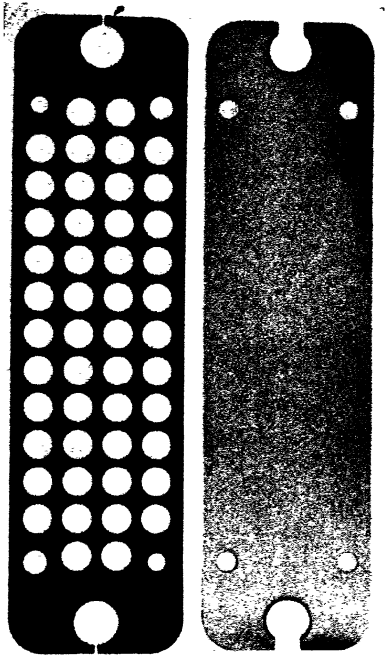
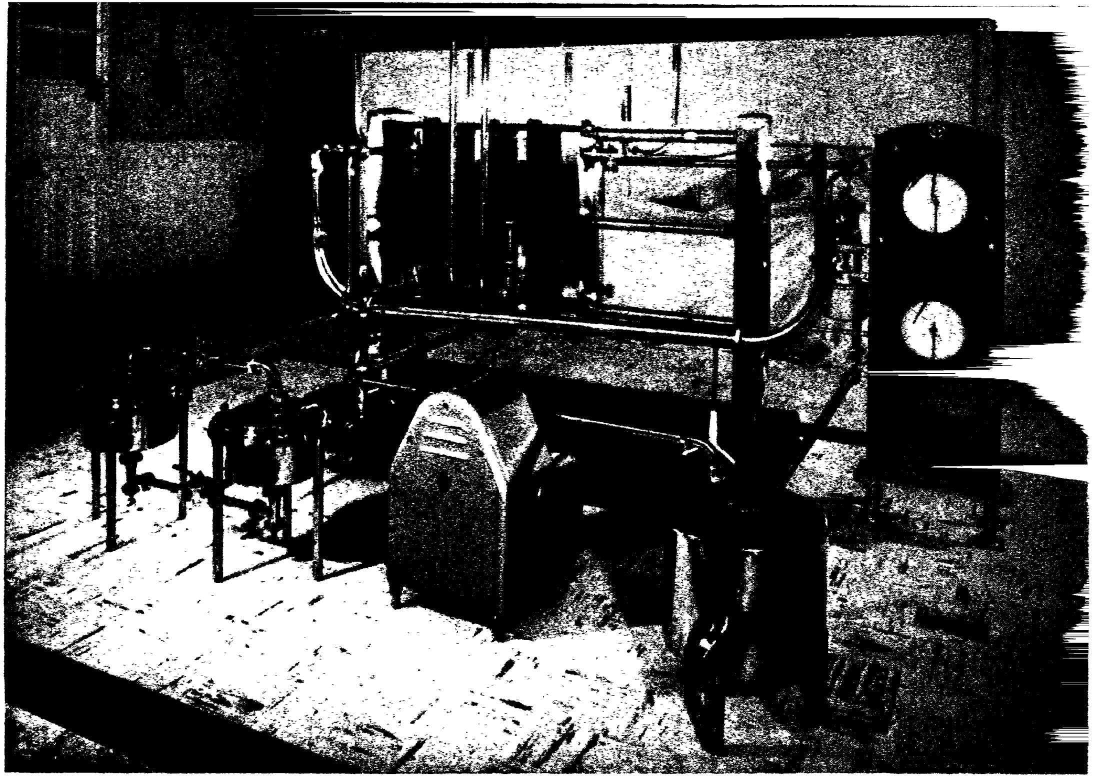


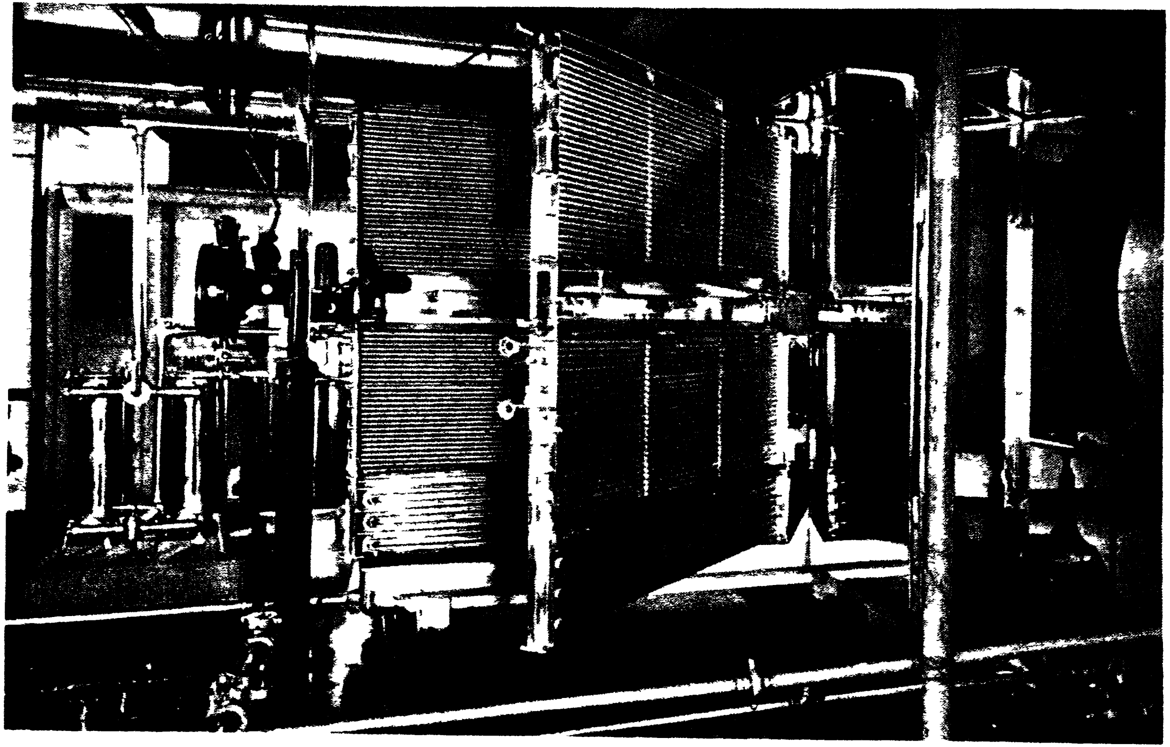
FIG. P 16A.—*Creamery Package H.T.-S.T. Plate.*

Right. *Smooth Stainless Steel Plate.*
Left. *Rubber Combined Gasket-Plate.*



[Photos by courtesy of Creamery Package Ltd.

FIG. 16B.—*Complete Creamery Package H.T.-S.T. Plant.*



[By courtesy of Graham Enock Mfg Co Ltd

FIG P 17—*H T-S T Plant*

milk tank. The first quantity of milk which is then diverted into a churn can be tested and re-pasteurised if up to standard.

When finishing at the end of the day's run the plant can be immediately stripped after thorough flushing through with water and the cleaning operations proceeded with (*see* p. 246). If, however, the stop is merely made in order to prevent the accumulation of milk stone during the day's run, the following procedure may be used for H.T.-S.T. plants:

The milk flow section of the plant is short-circuited and a hot solution of sodium hexametaphosphate added to the hopper and circulated for about 15 min. A suitable detergent may then be added to complete the cleaning process and, after a further 15 min. circulation at a temperature of about 160° F., the cleaning solution is finally drained off and hot water once more washed through. A short period (20 min.) of sterilisation follows and then the starting-up operations are once more put into operation and the next stage of the run is started.

General Maintenance and Control of Pasteurising Plant. Although Batch, Holder, and H.T.-S.T. equipments differ considerably in their design, the same fundamental requirements apply to all three types of plant, as far as maintenance and control are concerned. These may be summarised briefly by the following points:

(1) The makers' instructions should be studied in detail and meticulously followed.

(2) The equipment should be kept in a thoroughly clean condition.

(3) Unnecessary force should not be used in dissembling and assembling.

(4) One person should be made immediately responsible for the efficient working of the plant. This will usually be a foreman or charge-hand.

(5) Expert advice should be obtained if there is the slightest suspicion of any faulty running or abnormal behaviour.

(6) Spares should be available at a moment's notice.

The following points apply individually to the three types of plants:

Batch Pasteurisers. It is most important to ensure that the internal surface of the inner tank is completely free from any milk residues. At all times the surface should be absolutely smooth and there should never be any scratches or marks due to the use of abrasives in cleaning. Deposits not only lead to bacteriological trouble and poor keeping quality, but also decrease heat transfer. The efficiency of heating will depend on the efficiency of agitation, and regular checks should be made to ensure that there is no belt slip and that all bearings are properly lubricated.

Thermometers should be removed, cleaned and examined every day. All seals and glands should be inspected regularly, and particular care taken to ensure that these are thoroughly clean and rinsed through during the cleaning and sterilising operations.

The outlet valve is a common source of trouble in the Batch pasteuriser, and must be maintained in perfect condition. In a well-designed plant the raw milk intake is arranged through the top of the tank. If a common inlet and outlet are employed, most scrupulous care must be taken to ensure most thorough cleaning and sterilising, and that these are maintained in perfect condition. Steam valves, reducing valves and steam traps should be examined daily.

Holder Pasteurisers. Most Holder plants have mechanically operated filling, holding and discharging arrangements. Not all plants are equally well designed and if there is any possibility of forward leakage (contamination of the outgoing pasteurised milk by the raw or incompletely pasteurised milk in the Holder), this point must be specially watched. Well-designed machines have a " leakage groove " to ensure that if leakage does take place the leaking milk finds its way to the outside and not to the pasteurised milk, which has been passed forward.

All such valves and safety mechanisms should be inspected daily. Pumps are specially important, as if they are not scrutinised the finished milk may be pumped at a higher rate than the raw milk, with the result that air will be drawn in and cause froth in the pasteurised milk. Froth can not only result in under-pasteurisation, and consequently failure on the phosphatase and methylene blue tests, but also can lead to scaling in the heat exchanger and difficulties in filling. If vacuum filling is employed, joints must be inspected daily and renewed when necessary.

H.T.-S.T. Plants. Today plate exchangers are practically universal, and are employed for both H.T.-S.T. and Holder plants. The crucial item of equipment in these is the rubber gasket or jointing. It is essential that all these gaskets are in perfect condition, as a single faulty gasket, whether the trouble is because of displacement or deformation, can result in leakage, and in an effort to overcome this, the operative will nearly always tighten the whole set of plates, which invariably leads to further trouble for the remaining gaskets. If the gaskets are detachable, they can be replaced by the operative, but where the gaskets are bonded to the plates, these should be returned to the manufacturer when due for renewal. It is false economy to renew only some of the gaskets. The whole set for any one section should always be renewed together. To avoid over tightening, most equipments have a stop fitted on the spindle, and this should not be moved without the approval of the manufacturers.

An important point to watch is the temperature difference between the milk and the heating medium (hot water) in the heating section. Data for normal running are provided by the manufacturers and any deviation from these indicates either a difference in flow rate or a deviation in rate of heat transfer which may be due to, *e.g.* deposit on the plates. An increased temperature difference invariably means that the rate of milk flow has increased or the hot water flow rate decreased, or that the plates have become coated with milk stone. The rate of flow of both water and milk can readily be calculated by measuring in churns or other suitable receptacles, the quantity of milk or water passed in a given time.

Instruments are an important item in the Holder and H.T.-S.T. plants (*see* p. 546).

Mercury-in-glass thermometers should be regarded as fragile items and treated with the greatest care. It is advisable to have some convenient rack handy where the thermometers may be placed during the cleaning operations.

The filtering devices for the compressed-air supply must be checked regularly, as all pneumatically operated instruments can be seriously affected by water or oil vapour. The compressor is normally placed below the instruments in order that condensate in the system will drain back, and so can be blown off at regular intervals. Steps should be taken to ensure that the blow-off mechanism is functioning properly.

All pumps, whether of the centrifugal or positive type, should receive regular inspection. Special attention should be paid to the glands. If the motor drive employs a belt, this should be inspected at regular intervals and any slack taken up.

The flow controller and flow diversion parts should be inspected daily and care taken that they are functioning properly, and that there is no accumulation of foreign material.

PASTEURISATION IN BOTTLE. Heating and cooling of milk within a sealed bottle is obviously the ideal approach to safe milk and long keeping quality, and it is therefore not surprising that this method has been tried for many years, although with a limited degree of success.

The process has, until recently, been based upon the normal holder treatment at 145° to 150° F. for 30 min. The milk, after filtration or clarification, is first heated to about 147° F. by means of normal equipment—usually in existing plants either a capillary surface heater or tubular heater, although a plate exchanger

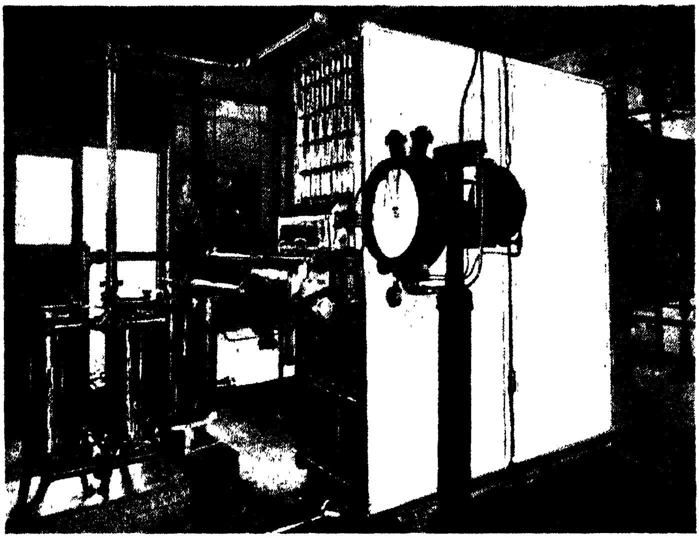


FIG. P 18.—*H.T.-S.T. Plant.*

[*Photos by courtesy of Graham Enock Mfg. Co. Ltd.*

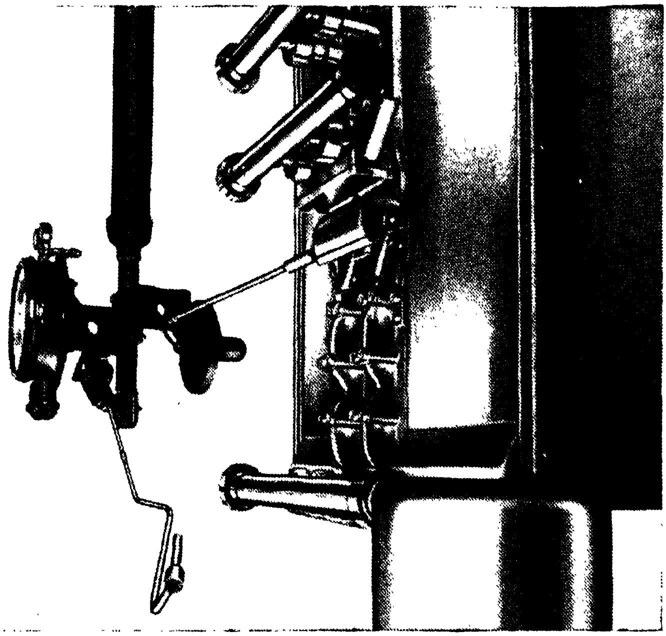
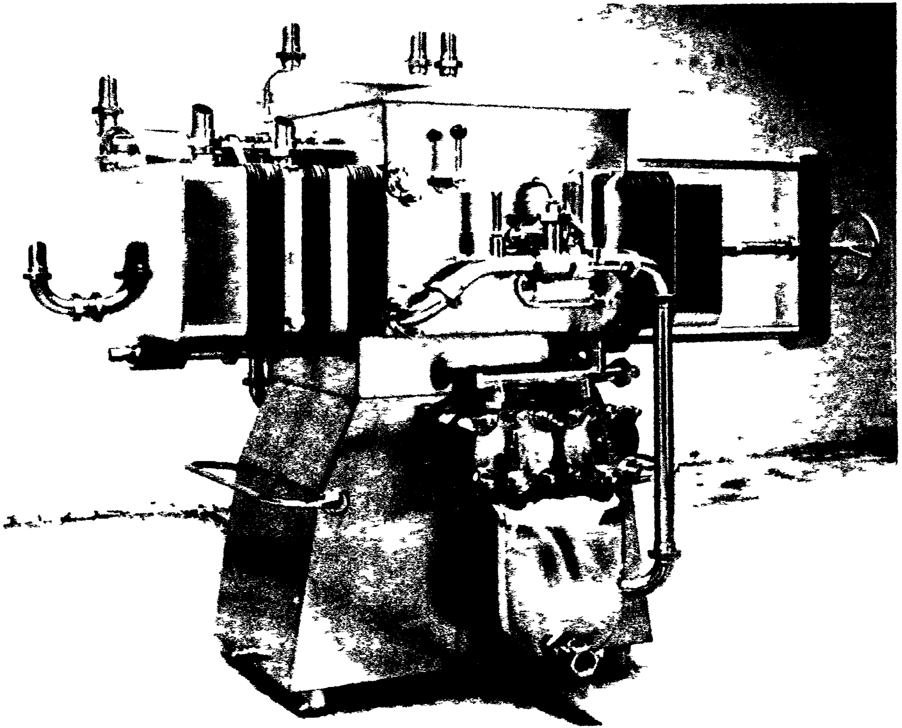


FIG. P 19.—*The Diversion Arrangement and the Instrumentation of the Graham Enock Plant.*



[By courtesy of Graham Enock Mfg Co Ltd

FIG. P 20 —"*Gem*" *Unified Short Time Pasteuriser* (500-2000 *g p h*) might be preferable. The hot milk passes immediately to the filler and is filled into hot bottles direct from the washer. The bottles of milk are then maintained for 30 min. at 145° F., cooled by passage through water tanks at declining temperatures, and conveyed to the cold store. The normal holding tanks, cooler, and pasteurised milk balance tanks are therefore eliminated, the bottle itself replacing these items of equipment. Consequently post-pasteurisation contamination is impossible and the process should be equivalent to laboratory pasteurisation.

Various plant designs have appeared, but have not survived in commercial use. All use a conveyor system, rather similar mechanically to those of bottle washers or continuous sterilised milk plants. The main differences in principle have concerned the method of holding. Two types of plant have been used in Britain:

(1) The sealed bottles of hot milk are passed through a tank of water maintained at 145° F. with immersion half-way through the 30 min. passage. Thence they pass through a cooling tank of warm water, followed by a series of water sprays at temperatures declining from 65° to 40° F. In this system, which is now rarely used, the bottles require a water-tight seal of the crown cork type

(2) The 30 min. holding period is obtained by conveying the hot bottles through a hot chamber maintained at 145° F.; this is the only plant which has achieved any degree of success in the past. The air passes by fan over steam coils, and is blown into the holding chamber. The air temperature is controlled thermostatically, whilst the chamber is insulated and closed at each end by double flaps. The bottles then pass through two cooling water tanks. In the first, water is used in counter flow, so that the hot bottles first meet the warmest water. The second tank contains circulating chilled water at 36° to 38° F. from a storage tank containing direct expansion coils. The cooling time is about 15 min. from 145° to 100° F., and 25 min. from 100° F. to 50° F., making 40 min. in all.

In this system the bottles remain upright throughout, with the closure one inch above water level. Consequently, there is no risk of water or milk leakage, and normal disc or foil closures can be used. Two conveyor systems have been employed:

(*a*) A vertical type (where floor space is limited) in which the bottles travel up and down and are handled singly. The bottles are suspended from individual carrier belts with a spring clip device which provides an air seal above the bottle.

(*b*) A straight-through horizontal tunnel, through which the bottles are carried in their standard metal crates. This type requires less labour and is preferable unless the output is very small.

Thermographs are fitted at the entry to the filler bowl and midway through the hot air chamber, with additional indicating thermometers at the beginning and end of the chamber. It is also possible to obtain very small thermographs which can be fitted to an individual bottle to provide a record throughout the process. Several plants operated on the foregoing lines are covered by British patents (Auto Dairy Engineers Limited now hold the patent rights of the process developed by Arthur G. Enock).

The in-bottle process offers very considerable advantages, which may be summarised as follows:

(1) The elimination of contamination after holding removes a major bacteriological difficulty inherent in normal methods of pasteurisation. No cooler, pipeline, or balance tank surfaces are involved. The bottle filler—usually a bacteriological problem—handles milk before pasteurisation instead of afterwards, and also does so at pasteurisation temperature. Moreover, the bottles themselves must be filled *hot* instead of cold, hence the bottle washer must provide

a final *steam* treatment instead of a cooling rinse. This in itself eliminates a major bacteriological problem of bottle washing. An additional safeguard is provided by the fact that the bottles and their closures are processed along with the milk.

(2) Other possible weaknesses of holder pasteurisation also disappear. Once the bottle is filled and sealed, no raw milk can gain access to it (*e.g.* through leaking valves), nor can there be any possibility of manual contact, infection by flies, etc. Underheating of milk foam in holders of normal plants is a serious problem; in the bottles foaming is negligible, and in any case the foam is also held at 145° F.

(3) In normal Holder plants considerable proliferation of thermophilic organisms occurs during long runs, partly because each new batch is inoculated by milk residues from a previous one. Some thermophilic growth occurs during in-bottle pasteurisation, but is not of practical importance. Each bottle is an individual unit and the time period of such growth in the bottle is strictly limited to 30 min.; the preliminary heater is the only important source of thermophiles.

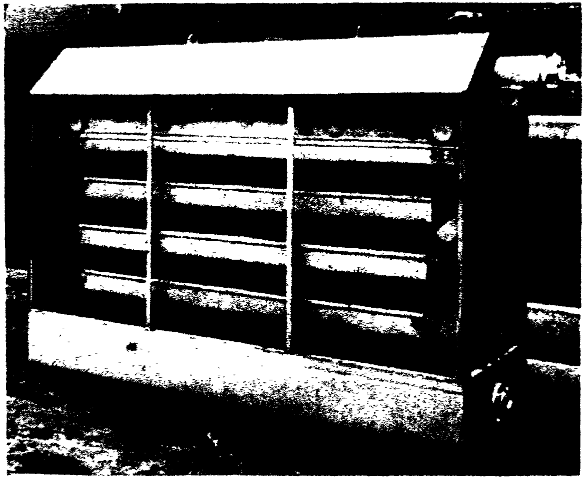
(4) The process offers a nearly " fool proof " method of producing safe milk, without reliance upon delicate control instruments.

(5) The labour, time, and cost of plant cleaning are greatly reduced, since the bottle itself replaces so many items of normal plants. Consequently the plant can remain in operation for a longer period of the working day—its advocates claim up to 20 per cent. longer—and consumption of water, steam, and detergents is reduced.

It is universally acknowledged that in-bottle pasteurisation represents the theoretical ideal, and in practice the process yields a superior product. In an investigation of several plants in the Midlands, Rowlands and Provan (*SAB* (1941), 27) showed that the in-bottle process yielded pasteurised milk containing fewer total bacteria and many fewer coliform organisms, and having a longer keeping quality than normal pasteurised milk. Similar results were obtained by Crossley (unpublished data), who found that the flora consisted almost entirely of thermoduric micrococci derived from the raw milk, and that coliform organisms were rarely present. (Theoretically coliform organisms should be absent, apart from the uncommon occurrence of a heat-resistant strain.) In practice the plate colony count of the in-bottle milk was rather lower than the laboratory-pasteurised plate count of the raw milk, due probably to additional destruction during the first stages of cooling of the plant samples. The additional keeping quality of in-bottle as against normal holder-pasteurised milk varied between about 12 hr. in hot weather and 2 days in winter conditions. This would be expected in view of the smaller bacterial population and the well-known fact that thermoduric cocci affect keeping quality only slowly. All users of the process agree that consumer complaints of souring are very rare.

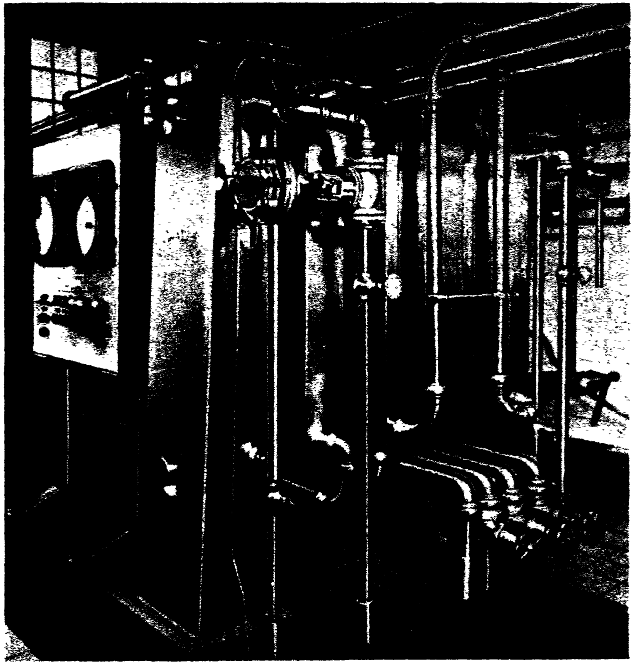
In view of the foregoing advantages, the failure of the process to secure universal adoption can only be explained by serious drawbacks. The earliest plants developed serious mechanical conveyor faults, and although this defect was remedied, the idea suffered a set-back. Other more permanent difficulties are:

(*A*) **Technical.** (1) The plant occupies an extremely large floor space, particularly in comparison with H.T.-S.T. plants. Adoption of the process would, therefore, reduce the possible output in a given building, and indeed the present national milk supply could not be handled in existing premises if the process became general. For this reason alone, large distributors have decided that in spite of its admitted advantages the in-bottle process would be impracticable. The size of the plant is, of course, due to the long holding tunnel and the series of cooling tanks. Whilst a reduction of the holding chamber could be made possible by holding the milk at a higher temperature for a shorter time, cooling must inevitably be slow to avoid fracture of bottles. Incidentally, it has been



[*By courtesy of Graham Enock Mfg. Co. Ltd.*

FIG. P 21.—"*Gem*" *KV Ice Water Cooling Unit.*



[*By courtesy of Dairy Supply Co. Ltd.*

FIG. P 22.—*Alfa Laval H.T.-S.T. Plant.*

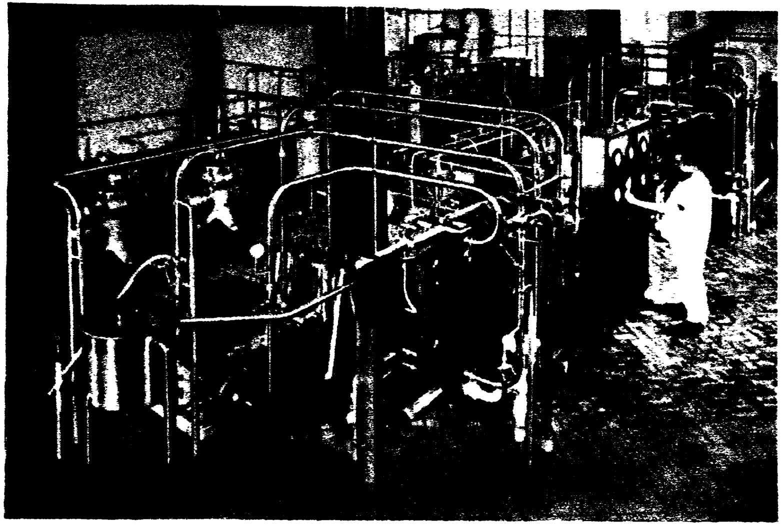


FIG. P 23.—*Silkeborg H.T.-S.T. Equipment.*

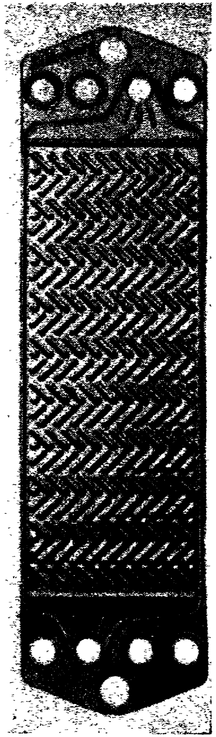
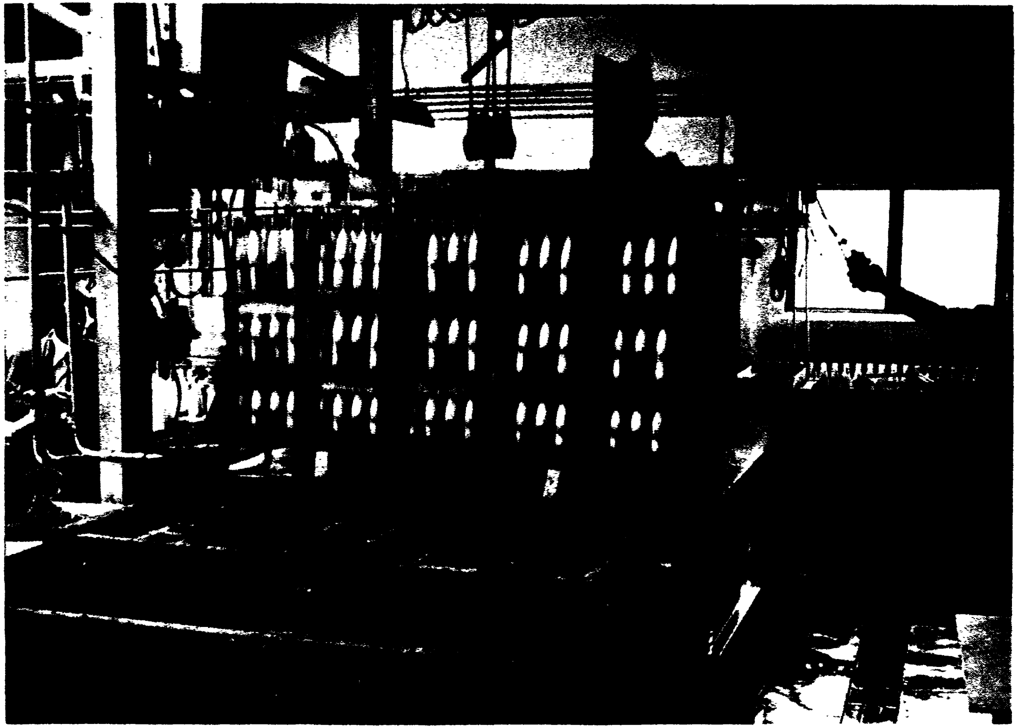


FIG. P 24.—*Plate of H.T.-S.T. Pasteuriser.*

[*Photos by courtesy of Hiron and Rempler Ltd.*



[By courtesy of Richardson's (Edmonton) Ltd.

FIG. Pi 1.—*Cradle and Travelling Hoist for Immersing Bottles in Water Tanks.*

shown recently that no measurable bacterial growth occurs during the slow cooling, nor is there any loss of nutritive value (both former points of criticism).

(2) Full regenerative heating, now regarded as a normal and essential feature of pasteurising plants, is not possible.

(3) Owing to poor heat transfer through glass, large quantities of cooling water are required. It is possible to make some use of the finished warm water leaving the first cooling tank by taking it to a bottle washer.

(4) The weight of the crates and bottles is carried through the plant in addition to that of the milk. (A standard crate of 20 full bottles weighs 59 to 63 lb., of which only 25·9 lb. is the weight of the milk.) The electric power cost is therefore higher than that of pumping the milk alone.

(5) The bottle must contain the legal measure of cold milk, but the milk is filled hot and occupies a larger volume. Allowance must be made for this when filling, and a special bottle must be used to allow for the extra volume of hot milk. After cooling there is an appreciable air space above the milk, rather an advantage to the consumer. However, the cost of the non-standard bottle is relatively high, and will doubtless remain so unless the process develops on a large scale.

(6) Hot bottle filling, although quite practicable, *e.g.* for sterilised milk, is admittedly more troublesome than cold filling.

(7) In a conventional plant the temperature of all the milk can be recorded, since it can be made to flow over the recorder bulb. In the in-bottle process it is only possible to record the milk temperature within selected individual bottles, which must be assumed to represent the whole. This point has been of concern to public authorities, but it is only fair to state that practical investigations have tended to justify the assumption.

Technically, therefore, the reduced costs of labour and plant cleaning must be balanced against increased costs of heating, water, power, and bottles, and the capital costs of buildings. No independent costings appear to have been published, but the general opinion seems to be that the in-bottle process is more costly.

(*B*) **Other Problems.** (1) It might be thought that, given a raw milk supply free from excessive numbers of thermoduric bacteria, no bacteriological difficulties could arise, but this is not entirely the case. Although, in fact, results usually are excellent, some plants have yielded samples showing unsatisfactory phosphatase tests and positive coliform tests, which in this case can only be due to inadequate heat treatment. In both the investigations previously mentioned, such failures were traced to a fall in milk temperature before the bottles entered the holding chamber. Loss of temperature may be due to (*a*) cooling of unfilled bottles, (*b*) cooling of milk in the bottle filler, (*c*) cooling of filled bottles during passage to the holding chamber. In practice any hold-up of bottles exceeding 5 min. duration, due to failure of the filler or capper, is usually fatal. The hot air chamber maintains the milk temperature at the initial figure, even with considerable variations (up to 10° F.) of air temperature. Consequently the milk remains at the temperature at which it enters the chamber, and if this is below 145° F. the correct temperature cannot be regained even by raising the hot air to 155° F. Thus milk which enters at the correct temperature cannot fail to be properly pasteurised, but if it does not the process fails.

It is therefore essential to maintain particularly careful supervision of bottle fillers and cappers, and to preheat the milk to 147° F. The latest plants introduced a water jacket at 147° F. around the filler bowl, heated metal plate loading platforms, and heated, shrouded bottle conveyors.

The foregoing plants were based upon milk treatment at 145° F. for 30 min., since no other process could be licensed under legal regulations. It has, however, long been known that there is a wide choice of time and temperature combinations which are equivalent to 145° F. for 30 min. or 161° F. for 15 sec. This fact was recognised in the new Milk (Pasteurised and Sterilised Milk) Regulations 1949, wherein (second Sched. Part 1, Article 1 (*c*)) local authorities are now given power to license any process of which they approve, subject to confirmation by the Minister. This clause is intended specifically to encourage the development of new processes, including the in-bottle process, by allowing the use of new combinations providing that the phosphatase test is satisfied.

For official control purposes the treatment has now been defined (1953) with reference to the milk and water temperatures and not to the total period of immersion. The schedule authorising use of the designation " Pasteurised " reads as follows:—

" The milk, which shall be contained in metal capped glass bottles not exceeding one pint capacity, shall be immersed in water which shall be raised to and thermostatically controlled at a temperature of 150° F. plus or minus 0·5° F. and the milk shall be maintained at a temperature of not less than 145° F. and not more than 150° F. for a continuous period of not less than 15 minutes, during which time it shall be retained at a temperature of not less than 148° F. for a period of not less than 6 minutes. Immediately after pasteurisation the milk shall be cooled to a temperature of not more than 50° F. A locking device shall be fitted to the heating tank to prevent removal of a cradle of milk bottles after a period shorter than the full immersion period required ".

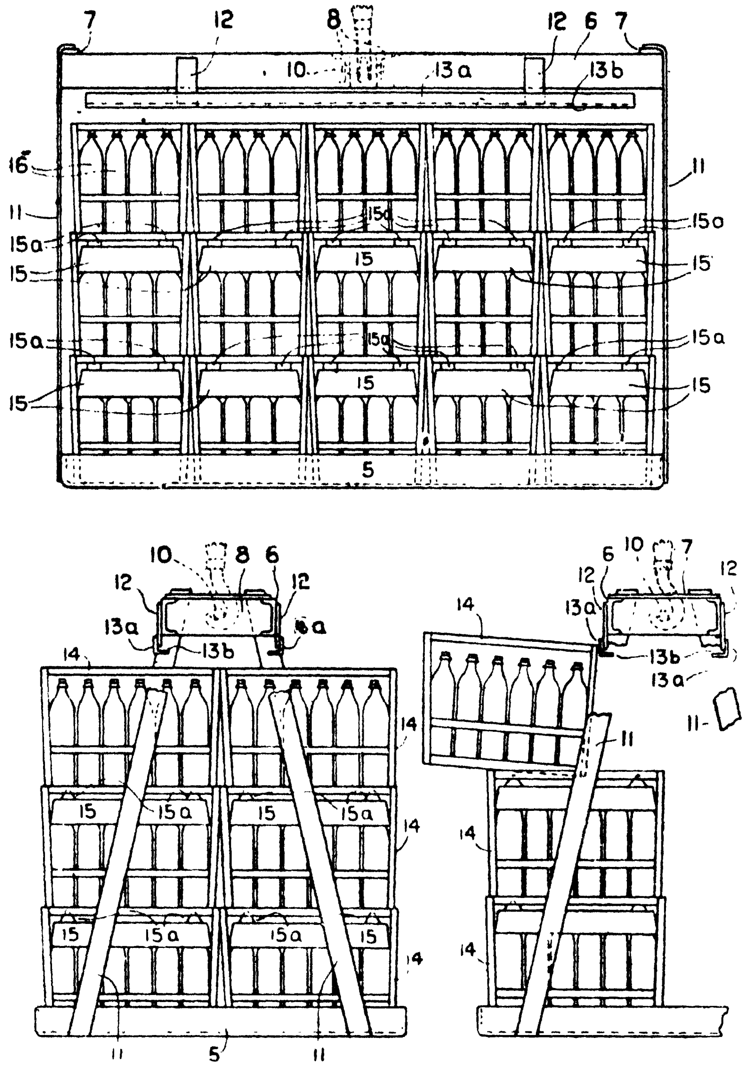
This treatment is equivalent to 145° F. for 31 minutes, and with existing plants will probably require a total immersion period of 40 minutes.

Interest in the in-bottle process has been revived, for whilst the large distributor remains unimpressed, the increasing numbers of small distributors who must now handle pasteurised milk may find the process well suited to their needs. In this field it offers the prospect of a very safe, fool-proof, and simple plant, which will give reliable results in the absence of laboratory control or the use of elaborate instruments.

One such recent plant devised by Fowler (Brit. Patent 604324—available under Licence of Right) has attracted attention in view of its extreme simplicity and the consistently excellent results obtained with it. The Fowler process introduces a new principle in that the milk is bottled cold, and the sealed bottles are then immersed for a fixed period in a tank of hot water. Consequently the milk is treated at a steadily rising temperature within the bottles, instead of at a fixed temperature.

The milk is preheated to 65° F., filtered and bottled. A normal type of bottle washer is used. The filled bottles are placed in metal crates (sterilised milk pattern) holding 24 pint bottles each, and 30 crates are packed (in four layers) into a special carrier cradle, giving a total batch of 720 bottles per cradle. The bottom three layers of crates are covered by air-seal trays which rest on the caps of the bottles. The cradle is lifted and lowered by a travelling hoist on an overhead runway, by means of which the bottles can be immersed for fixed periods in a series of water tanks (Figs. Pl 1 and 2).

The cradle is first lowered into a tank of hot water at either 153° or 150° F. The hot water is circulated rapidly by pumping and is heated by direct steam injection across the bottom of the tank through an open ¾ in. pipe. The water temperature is controlled by a thermostat which operates the steam diaphragm valve. A thermograph bulb is also placed in the tank at such a water level that it is immersed only when a cradle is present in the tank ; in this way a continuous chart record is obtained of both the hot water temperature and the time of immersion of each cradle. It is also possible to fit a mechanical device to prevent removal of the cradle before the expiration of a pre-determined period. An immersion time of 30 min. is used with water at 153° F., or 35 to 36 min. with water at 150° F. The water regains a steady temperature in 15 min. or less, and the milk attains 145° F. in 20 min. (water at 153° F.) or 25 min. (water at 150° F.) ; for the remainder of the period the milk rises above 145° F. Uniform



[*By courtesy of Fowlers Dairy Developments Ltd*

FIG. Pi 2.—*For Section Pasteurisation In-Bottle.*

5. Rectangular Base.
6. Longitudinal Members.
7. Transverse Straps.
8. Transverse Bars.
9. Lifting Bolt.
10. Lifting Hook.
11. Outwardly diverging straps.
12. Depending Hangings to Loading Gauge.
13. Loading Gauge.
14. Crates.
15. Air Seal Trays.
16. Bottles.

heating of the milk is not claimed, since the rise in milk temperature varies between different positions in the tank, and also at different points within an individual bottle. Detailed tests at two of these particular plants carried out by the National Physical Laboratory showed that in the coldest positions in the cradle the milk attained a final temperature about 1·5° to 2·0° F. below that of the water, whilst the hottest bottles rose to within about 0·25° to 1·0° F. of the water temperature. The coldest point within a pint bottle was about one inch from the bottom—in smaller bottles the variation is negligible. The process must therefore be based upon the coldest milk in the coldest bottle, and samples withdrawn for testing must include bottles which have occupied the coldest position. Once this determination has been made, the water temperature is a reliable indication of the process of pasteurisation. (Constant results are obtained at any individual position for a constant water temperature.) Wide variations in the temperature of the milk at bottling have no significant effect.

The bottles are then passed in succession to three cooling tanks, containing water at 110° F. (overflow to bottle washer), 80° F. (overflow to milk preheater), and chilled water at 50° F. from a refrigeration plant. The bottles are immersed in each tank for 15 min., giving 45 min. total cooling time. Thermographs are fitted to each cooling tank. The milk temperature falls to 10° F. above the cooling water temperature at each stage, and the cradles are finally transferred by the conveyor to cold storage (or to a lorry for transfer to cold storage at a sub-depot) where cooling is completed (Fig. Pi 3).

By alternate use of two heating tanks it is possible to start a batch every 15 min., giving an output of 300 gal. per hr. instead of 150 gal. per hr., with a single heating tank. The 300 gal. per hr. plant requires an area of about 21 ft. × 6 ft. to accommodate the two heating and three cooling tanks.

The bottle used is of sterilised milk type, but having a 36 mm. mouth, whilst the seal is a standard pattern metal foil cap of heavy gauge. The air-seal trays prevent water leakage into the bottles.

This process is of interest, since it utilises the greatly increased rate of bacterial destruction within the range between 145° and 150° F. It serves as a useful reminder of the fact that thermal destruction of the tubercle bacillus requires 10 min. heating at 145° F. but only 1½ min. at 150° F. Moreover, it is possible to determine the equivalents of temperatures between 145° and 150° F. in terms of pasteurisation at 145° F. These figures are given by Clegg and Lomax (1951), in a paper recording investigations of a Fowler plant in the Birmingham area, and from them it is possible to determine the extent of heating of the milk in terms of pasteurisation at 145° F. The corresponding figures are:

Temperature (T° F.)	*Time: min.*	*Ratio* 145°: T°
145	30	1·000
146	22	1·364
147	16·5	1·818
148	12·2	2·459
149	9·0	3·330
150	6·6	4·545

It is worthy of note that pasteurisation at 150° F. for 30 min. (the legal maximum for holder pasteurisation) is actually equivalent to 136 min. at 145° F. These authors report that over a period of several years the in-bottle plant gave more satisfactory results than others in the area, and that the milk was of superior keeping quality. Only the in-bottle samples showed no phosphatase test failures and no coliform organisms throughout the period. Using a 30 min. immersion period in a water bath at 153° F., and sampling from the coldest bottles, the phosphatase test became satisfactory at about 22 min. (milk temperature 147° F.). This represented an extremely large safety margin, since the milk temperature rose to 151° to 152° F. during the remainder of the period. Moreover,

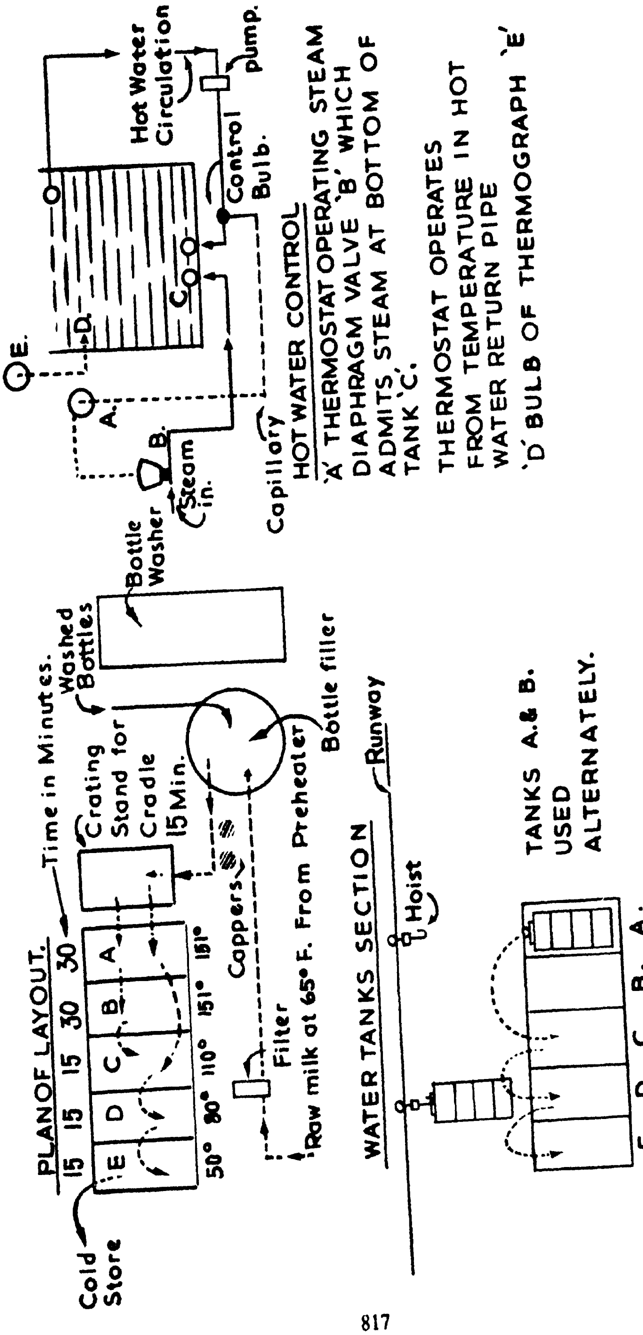


FIG. Pi 3. Flow Scheme for " In-bottle " Pasteurisation.

comparisons between rapidly cooled samples and slowly cooled plant samples revealed no differences in phosphatase results or plate colony counts. A method of calculating the pasteurisation time corresponding to a given temperature has also been published by Bell (1943).

Investigations at a second Fowler plant by Crossley (to be published) covered two alternative processes, viz. (1) the original process of immersion for 30 min. in a water tank controlled at 153·5° F., in which the water regained a temperature of 153° F. during the last 15 min. and the milk attained a final temperature of 151° to 152° F., (2) immersion for 35 min. in the same water tank controlled at 150° F., in which the water regained a temperature of 150° F. during the last 20 min. and the final milk temperature reached 149° to 149·75° F. Both processes were satisfactory, and were equivalent to a minimum of 31 min. at 145° F. In these experiments the in-bottle milk was compared with samples of the same milk supply subjected to laboratory pasteurisation at 145° F. for 30 min., the plant samples being selected from the known coldest points in the heating tank.

The 30 min. immersion yielded satisfactory phosphatase tests after 22 to 24 min., and the 35 min. immersion after 27 min. The phosphatase figures dropped from very high values to the final steady value within a short period of about 2 min. in the range of rising temperature from 145° to 147° F. The colony count figures and statutory methylene blue reduction test figures become equal to those of laboratory-pasteurised milk quite early in the immersion period, roughly when the milk temperature reached 146° F. Coliform organisms also disappeared at quite an early stage. The keeping quality was equal to, or better than, that of laboratory-pasteurised samples. No evidence was obtained of increased bacterial numbers or impaired keeping quality resulting from slow cooling; indeed, there were indications of a reverse tendency. The only serious problem was control of cream-line destruction, always rather critical with in-bottle pasteurisation. The 30 min. process gave cream-line losses ranging from 20 to 40 per cent., but the figures dropped to 8 to 12 per cent. when the 35 min. process was used. This latter process has now been adopted. It possesses the additional advantage that the milk temperature in the hottest bottle cannot exceed 150° F. (Legally the plant should incorporate a flow-diversion valve if temperatures above 150° F. are used.)

In brief, it is claimed that the process combines certainty with simplicity. Only one control instrument (hot water temperature) is essential, and this is of a simple, robust type, in which very rapid response is unnecessary. The difficulties of hot bottling are avoided, and since the whole process is completed in the bottle, the risk of temperature losses before holding is overcome. Moreover, plant cleaning is reduced to the simplest possible terms. There is practically no plant to be cleaned, and the process is easy, since only cold milk is handled. (Hot milk is handled entirely within the bottles.) The total daily cleaning time is claimed to be about 20 min., and no detergent is needed apart from the bottle washer. At one such plant the total labour force comprises:

Two men tipping milk, operating milk filter, bottle filler and capper, and miscellaneous duties.

Two women operating bottle washer.

One man crating filled bottles, passing them through the process tanks, and loading finished bottles on to lorries.

See Clean milk production; Instrumentation; Pasteurisation.

Refs.: Bell (1943), *IEC*, **35**, 71; Clegg and Lomax (1951), *SAB*, **14**, 23; Rowlands and Provan (1941), *SAB*, p. 27.

PASTEURISATION BY OTHER METHODS. Many attempts have been made to pasteurise milk commercially by such agents as ultra-violet irradiation, electricity, ultra-sonic waves. Some of these have achieved a measure of success in securing a reduction of bacterial count but in some cases do not invariably secure the total destruction of T.B. which has come to be accepted as the criterion for successful pasteurisation. The present position may be summarised by saying that the modern H.T.-S.T. treatment is cheap and efficient and only a really efficient and economic non-heat treatment process is likely to supplant it. *See* Pasteurisation, alternatives to (p. 827).

"ELECTROPURE" PROCESS OF PASTEURISATION. This process involves the passage of a low-frequency alternating current through milk by means of conducting electrodes in contact with the milk. After early work on the effects of direct and low-frequency alternating currents on bacteria, the first experiments with milk were carried out by Thornton. He found that sterilisation could be obtained with direct currents, but that undesirable electrochemical reactions also occurred. In particular, curdling took place in the vicinity of the positive pole. When he employed low frequency alternating currents, however, no ill effects were noted and sterility was obtained. Since milk contains chloride ions, it is a conductor of electricity, but a rather poor one, so that the passage of electricity involves the dissipation of power and the production of heat. In Thornton's experiments, the temperature of the milk was allowed to rise to 150 F. and he ascribed the sterilising action to this fact.

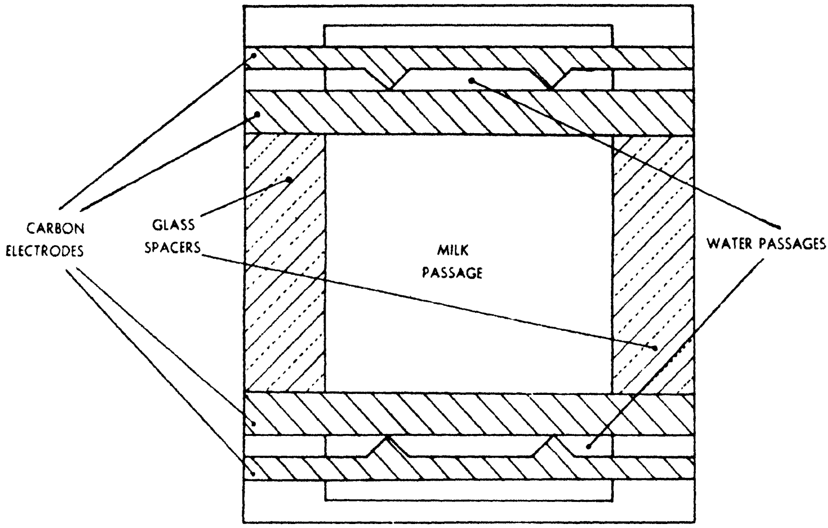


FIG. P 25.—*Section through "Electropure" Heating Chamber.*

Much work on similar lines was carried out by Beattie and Lewis. In preliminary work with direct currents they found no sterilising action, although they found the same ill effects as Thornton. They later developed a continuous process in which high voltage 80 cycles per sec. power was used. About 30 gal. of milk per hr. could be treated, and over a long period of time bacterial destructions of better than 99·5 per cent. were obtained with the milk heated to less than 150° F. at its point of exit from the apparatus. The taste and chemical composition of the milk were unchanged, and as far as could be ascertained its nutrient value was unaffected.

Beattie and Lewis claimed that the milk was not held at an elevated temperature long enough for the reduction in the bacterial count to be a purely thermal effect, and they considered that some other mechanism was involved. Leith and Lodge also carried out tests on the apparatus, and, while agreeing that the results obtained were as reported, they believed that heating was solely responsible.

PASTEURISATION BY OTHER METHODS

The development of pasteurisers using the principle of electric treatment followed in the U.S.A. and in Holland, using the "flash" principle in which the milk was not held at an elevated temperature for any clearly defined time, but was cooled almost immediately after treatment. This method, described by McDowall, gave sufficiently good results in many cases when the milk was heated to temperatures of 155° F. to 170° F. at the outlet of the heater unit. It was, however, very dependent for its results on the skill and care of the operator. When the H.T.-S.T. treatment cycle was accepted, a holding unit was added after the electrical heating unit. The "Electropure" plant as now used mainly in the United States therefore follows the same general principles as the plate pasteuriser, with the replacement of steam heating by electrical resistance heating.

A cross-section of a typical heating chamber is shown in Fig. P 25. The milk passage (A) of rectangular section, is bounded on two opposite sides by carbon electrodes (B) and on the other two sides by glass spacers (C). A water passage (D) at the back of each carbon electrode allows water to be sprayed on the rear surface of each electrode. The purpose of this is to maintain the carbon at a uniform temperature, so that a uniform distribution of the heating current over the electrode surface is obtained. Carbon supports in the water passage strengthen the electrodes.

The temperature of the milk is measured at the outlet of the heating chamber, and an automatic control system maintains this temperature at the required value. A flow diversion valve is also fitted at the end of the holding unit.

Experimental work on the use of electrical resistance heating as a means of reducing the time for pasteurising is continuing. Supplee and Jensen have shown that treatment times as short as 0·8 sec. with temperatures of the order of 180° F. give better than 97 per cent. reduction in the bacterial count.

It is now generally accepted that the destruction of bacteria in the "Electropure" process is due to the heat developed in the milk, and the operation of the process on the H.T.-S.T. cycle is based on this assumption. It is probable that a slight electrochemical effect also exists, since electrolysis occurs to some extent even with alternating currents up to a frequency of about 1500 cycles per sec., but this effect is normally masked by that of heat.

The principal advantage claimed for the "Electropure" system is that there is no temperature gradient from a hot plate surface since the heat is generated uniformly in the milk. No part of the milk is even momentarily above the nominal pasteurising temperature, so that there is less danger of cooked flavour and less destruction of vitamins. However, with modern high-efficiency plate units, the heat transfer is so good that the heating water itself need only be some 3° to 5° F. above the actual pasteurising temperature. The additional improvement on this count cannot, therefore, be expected to be large.

Economic factors have to be considered in comparing the "Electropure" process with the hot-water type of H.T.-S.T. plant. It is not possible to give precise operating figures, but in general where both the electricity and the hot water have to be derived from coal as the original source of energy, then the electrical process will be the more expensive. This follows since the generation of electricity from coal is itself a relatively inefficient thermal process (less than 30 per cent. efficient). Where other factors operate, such as, for example, where electricity is generated from water power sources, and where coal is expensive and has to be transported for long distances, then the electrical process may prove to be the cheaper. For plants situated in the British Isles, coal is normally the prime source of energy and the first set of economic conditions exists. Therefore, unless there are counteracting factors particularly applicable to any one case, the electrical process is unlikely to be extensively used.

Refs.: Thornton (1912), *PRS* (B), **85**, 331; Beattie and Lewis (1920), *Med. Res. Ctte., Sp. Rep.*, No. 49; McDowall (1929), *N.Z. Jour. Sci. Tech.*, **10**, 275; Supplee and Jensen (1941), *DI*, **6**, 125.

PASTEURISED MILK, TESTS FOR. From the first, pasteurised milk had to satisfy a plate count of 100,000 per ml. but in the last few years the increasing emphasis on keeping quality has revealed the shortcomings of the plate count. Since 1946 the official tests have been the *phosphatase* (p. 834) and a specially modified *methylene blue* test (p. 698).

The first of these tests ensures adequate heat treatment as illustrated by the following table :

	30 *min.*		15 *sec.*	
	° F.	° C.	° F.	° C.
To kill T.B. . . .	138	59	158	70
To destroy phosphatase .	142	61	160	71
Pasteurisation requirement .	145	62·8	161	71·7

and the second ensures a reasonable keeping quality under commercial conditions.

INTERPRETATION OF LABORATORY TESTS ON PASTEURISED MILK

The following examples illustrate the value of the various tests

Phosphatase	*Plate count*	*Coli*	*Lab. re-pasteurisation (% surviving)*	*Probable explanation*
1. *Sample direct from holder*				
Satisfactory	Low	Absent in 1 ml.	Nearly 100	Good raw milk efficiently pasteurised.
Satisfactory	High	Absent in 1 ml.	Nearly 100	Raw milk of high thermoduric count efficiently pasteurised.
Satisfactory	—	Present in 1 ml	—	Raw milk contains heat resistant coli (very rare).
Unsatisfactory	—	—	—	Inefficiently pasteurised (temp. too low or holding time too short).
2. *Sample from bottled milk*				
Satisfactory	Low	Absent in 1 ml.	Nearly 100	Good raw milk efficiently pasteurised with no re-contamination.
Satisfactory	High	Present in 1 ml.	Appreciably less than 100	Efficient pasteurisation, but recontaminated in plant.
Satisfactory	High	Absent in 1 ml.	High	Efficiently pasteurised with no recontamination but raw milk of high thermoduric count.
Unsatisfactory	High	Present in 1 ml.	Appreciably less than 100	Inefficient pasteurisation or recontaminated with raw milk.

See also Davis and Ashton (1951), *JSDT*, **4**, 78.

PASTEURISATION, OBJECTIONS TO. All objections to pasteurisation fall into one of two classes. (i) Those based on the assertion that the milk is damaged in one way or another, and (ii) those of an economic or political nature.

Objections in the first group may be further classified into nutrition, immunity, and palatability aspects. The more important of these objections are briefly reviewed below.

(*a*) Pasteurisation significantly lowers the nutritive value of milk. Of all the recognised constituents of milk, it is now generally admitted that only two are appreciably affected by heat, vitamins B_1 and C, and these suffer destruction to the extent of 10 to 20 per cent. Milk is not particularly rich in either of these vitamins ; of our daily requirements, 1 pint of milk supplies only 15 to 30 per cent. of B_1 and 20 per cent. of C. In effect, we rely on other foods, especially vegetables and fruit, for these vitamins. Moreover, it is not pasteurisation as such which destroys vitamin C, but previous or simultaneous exposure to light, especially in the presence of copper. Keeping the milk in the dark and removal of oxygen by de-aeration minimises this loss on pasteurisation. The desirability of slightly carbonating milk (adding carbon dioxide) after pasteurisation and before bottling might be considered. Such a carbonation would improve the flavour, diminish loss of vitamin C, and possibly improve keeping quality. We should remember that the vitamin C content, although small, is distinctly useful ; in the U.S.A. the cows produce roughly the same amount of vitamin C as the citrus fruit trees. Many experiments have been made to compare the nutritional effect of raw and pasteurised milk, but no completely satisfactory experiment has ever been made with children. Very carefully controlled experiments by Kon and Henry at Shinfield, using rats, failed to show any significant differences between raw and pasteurised milk. Other workers have also failed to obtain significant differences when using mice, rats, calves, and children. The experiments with calves were particularly interesting, as a proportion of the calves fed on raw milk contracted tuberculosis, but none of the calves fed on pasteurised milk did so. (*See* p. 759.)

Other objections are less important. They include the following claims :

(*b*) Consumption of pasteurised milk is more likely to lead to decay in teeth than if raw milk is consumed.

(*c*) Pasteurisation fails to destroy bacterial toxins in milk.

(*d*) Pasteurisation affects the disease-resisting property of milk.

(*e*) Universal pasteurisation would lead to the elimination of tuberculosis of the bovine type, and so result in an increase in tuberculosis of the human type.

(*f*) Pasteurisation would discourage the eradication of disease in dairy cattle.

(*g*) Pasteurisation would remove the incentive for producers to deliver clean milk.

(*h*) Pasteurisation affects the palatability of milk (Table P III).

(*i*) Pasteurisation is often inefficient.

(*j*) Pasteurisation enables the distributor to sell stale milk to the public, and so eliminates the necessity for the dairyman to get milk from the farm to the consumer as quickly as possible.

(*k*) It is wrong to interfere in any way with Nature's perfect food.

With the exception of the last three, it may be said that all these are either wrong or that there is no conclusive evidence on the subject. All interested persons are strongly recommended to read the excellent discussion of the subject in G. S. Wilson s book, *The Pasteurisation of Milk*. The ante-penultimate objection was formerly only too true, but today pasteurisation is, with the usual few exceptions, very efficient. The last objection cannot, of course, be controverted. A person's belief is not susceptible to reasoned argument. We can only point out that we bake bread, roast meat, fry fish.poach eggs, boil or steam vegetables, and stew fruits. All these processes involve far more drastic heat-treatment than that involved in pasteurisation. Why should any person object to the pasteurisation of milk?

The utilisation of milk in the household. Before coming to a final conclusion on this controversial question let us consider what happens to the milk when it reaches the household, which, after all, is the most important aspect.

Milk may be used for cooking, for making coffee, cocoa, or any one of the health drinks, for making tea, with breakfast cereals or fruit, or it may be drunk raw as it comes from the retailer. It will be evident, therefore, that a large proportion of the milk will in any case be raised to boiling-point. According to Murray and Rutherford (1940), about 19 per cent. of milk is drunk raw, 7 per cent. with cereals, etc., 11 per cent. for milk drinks, 27 per cent. for cooking, and 36 per cent. for tea, coffee, and cocoa. In other words, about 60 per cent. of the milk is boiled and only about 27 per cent. consumed raw, assuming that about half of the cereal and milk drinks utilise raw milk. Even the most obdurate opponents of pasteurisation must admit that boiling does much more harm to milk than pasteurisation. The logical course, then, for opponents of pasteurisation would be to launch a campaign to stop the cooking or boiling of milk in the home and to insist that all or most of it is drunk raw. If we assume that boiling effects twice as much damage to vitamins B_1 and C as pasteurisation, it is evident that pasteurisation of all milk would have no worse effect than the boiling of one-half of it. Apart from the destruction of vitamins, etc., boiling milk in the saucepan can result in a mechanical loss of 10 to 15 per cent., due to the precipitation of protein, fat, and lime salts on the saucepan. Milk should, therefore, never be boiled unless necessary ; heating to 160° F. (71° C.), will not only make it warm enough for a hot drink, but will kill all disease germs and avoid heavy loss in nourishment.

TABLE P III—MILK-TASTING EXPERIMENT : ANALYSIS OF RESULTS (Wilson)

Raw milks	14	Pasteurised milks . . .	16
No. of observers	9	Total no. of observations .	270

Total no. of observations describing milk as Raw . . . 142
Total no. of observations describing milk as Pasteurised . . 128

Observer no.	*Described Raw as Pasteurised*	*Described Pasteurised as Raw*	*Total no. of mistakes*
1	6	6	12
2	9	10	19
3	4	7	11
4	7	9	16
5	4	4	8
6	8	8	16
7	7	10	17
8	7	10	17
9	4	8	12
Total . .	56	72	128
Expected no. .	63	72	135

This table shows that of nine observers only one proved to be able to detect pasteurised milk with any degree of consistency, making only eight mistakes instead of fifteen assuming that only chance operated.

Pasteurisation in the tea cup. The upholders of raw milk doubtless regard pasteurisation as most destructive treatment for milk, and some have referred to pasteurised milk as " pernicious poison ". Possibly they have never thought about what happens to milk when they put it into tea. Usually they are pasteurising the milk. A typical cup of tea is served at a temperature of about 150° F. ;

tea served at any lower temperature would doubtless be regarded as cold. since most of us like to sip our tea at about 145° F. The reduction of bacteria in milk as the result of making a cup of tea is about the same as that obtained by pasteurising it. The temperature-time data obtained by experiment shows that the heat treatment is approximately the same as in pasteurisation. Logically, therefore, opponents of pasteurisation should insist that no milk is used for cooking in any way, and that all hot milk drinks are served so mildly warm that probably no one would enjoy drinking them.

The position may be summarised as follows :

(1) There is no proof that milk contains in large amounts a heat labile vitamin or other essential constituent that is absent or present in only small amounts in other foods. While it would be foolish to deny the possibility of the existence of such a substance, all the evidence is strongly against the supposition.

(2) Much of the milk consumed is boiled or heated far more drastically than is required for pasteurisation. Even making a cup of tea does about as much damage to milk as pasteurisation. Only a fraction of the total is consumed raw.

(3) The most valuable constituents of milk—namely, the minerals, especially calcium and potassium, the protein, the vitamins A, B_2, and D, and the fat—are all known to be unaffected by pasteurisation. A small proportion of B_1 and C is destroyed in pasteurising, but most of our B_1 and C is obtained from vegetables and fruit.

(4) In practice it is impossible to ensure a safe supply of raw milk for the whole community. Pasteurisation is the simplest and cheapest method of treating milk to make it safe. It is apparent, therefore, that the objections to pasteurisation raised by so many well-meaning people are from a common-sense point of view greatly exaggerated. The public should, therefore, not oppose pasteurisation, but demand that it be done properly.

(5) The only valid objection to compulsory universal pasteurisation is the problem of the producer-retailer. Here the objection is not so much to pasteurisation as such, but to the economic threat of the combine or big firm to the individual. The specification of areas (p. 610) now permits only designated milk to be sold, which makes it obligatory for all distributors to sell pasteurised, sterilised or T.T. milk in bottles.

Long term policy. One further aspect is of interest. Many intelligent persons raise the following question : " We agree that under present conditions pasteurisation is a necessity, but will it be possible one day to deliver safe raw milk to the public as a whole ? "

It is, of course, theoretically possible, but before we can consider this prospect we shall have to insist on the following minimum conditions : (1) Regular medical inspection of all personnel handling milk in the farm, in the creamery, and in the distributing depot. (2) Regular veterinary inspection of all cows and specific examination for T.B., *Brucella abortus*, and *streptococci*. (3) Control of cow sales, *i.e.* preventing the sale of diseased animals. (4) Compulsory cleaning and sterilising of all utensils and equipment coming into contact with milk. (5) Compulsory cooling of milk to 45° F. or lower within 2 hr. of production. (6) A system of distribution which ensures that the milk is cooled to 40° F. at the depot, and that the temperature never rises above 50° F. in the course of distribution. (7) Universal refrigeration in the home.

Assuming that all these conditions are fulfilled, a supply of sweet (non-souring) milk could be guaranteed to the consumer and regarded as reasonably safe. No absolute guarantee of safety (in the disease sense) could be given with any system of milk distribution other than efficient " in-bottle " pasteurisation or sterilisation.

PASTEURISATION OF MILK FOR CHEESEMAKING. Although general interest in the pasteurisation of milk for cheesemaking is of quite recent growth, the possibilities of heat treatment have been recognised for at least 45 years.

As long ago as 1909-13 systematic experiments were carried out at Reading and Wisconsin to investigate the effect of pasteurising milk by various methods and to find what modification in the making process might be required.

Milk intended for liquid consumption is pasteurised for two reasons: (1) to kill pathogenic micro-organisms and (2) to improve the keeping quality. Very little is known of pathogenic bacteria in cheese. The acid conditions in cheese, however, must be unfavourable for pathogenic organisms, so that proliferation is unlikely. Some types of bacteria, especially the acid-fast such as the tubercle bacillus, can survive in cheese for months however (*see* Diseases). The cheesemaker is concerned chiefly with the economic aspects and milk is pasteurised for cheesemaking for the following reasons: (i) to destroy fault-producing bacteria; (ii) to give a more uniform product; (iii) to increase the yield.

All other reasons given really come under one of these three headings.

The objections raised against pasteurisation are: (i) It results in the absence of typical flavour and body; (ii) it entails longer ripening; (iii) it encourages the use of low-quality milk; (iv) it increases the cost of manufacture.

The destruction of bacteria. This is the prime requirement of pasteurisation. Fortunately all the common fault-producing organisms, *e.g.* coli-aerogenes bacteria, yeasts, moulds, *L. rudensis* (the " red spot " organism) are, like the pathogenic bacteria, destroyed by efficient pasteurisation. A useful index in this respect is the tubercle bacillus (*Myco. tuberculosis*). If milk has been heat-treated sufficiently to destroy T.B. it may be assumed that most types of economic interest have been destroyed as well. (The spore-forming butyric acid bacteria are, of course, an exception.) Heating milk to 145° F. (62·8° C.) for 30 min. or to 161° F. (71·7° C.) for about 15 sec. will destroy T.B. and other pathogenic micro-organisms as well as taint-producing bacteria, and result in a negative phosphatase test. These time-temperature conditions have been arrived at by many hundreds of experiments in an attempt to find how to destroy the undesirable bacteria without producing a deleterious effect on the milk (*e.g.* reduced cream line, cooked flavour, longer renneting time).

For cheesemaking the high-temperature short-time (H.T.-S.T.) method has obvious advantages. Thus it is a continuous process and requires very little space and plant, and if equipped with the necessary precision-control apparatus works excellently in practice. *A temperature of* 161° *F.* (71·7° *C.*) *for* 15 *sec. is recommended as the maximum.* The most suitable temperature in the range 155-161° F. may be found by experiment. This may vary slightly according to the locality. A temperature of less than 155° F. (as used by some makers) leads to unnecessary risks and should not be used.

The commonest fault in the management of pasteurising equipments is the recontamination of the outgoing milk. Great care must be taken to follow the maker's instructions. All temperatures should be checked with standardised thermometers. The supervision of the plant, like the cheesemaking, should be in the hands of a properly trained person. *The whole of the advantage gained by pasteurising the milk may be undone by dirty methods in the cheese room,* e.g. *failure to clean and sterilise vats and utensils, pipelines, etc.*

With rare exceptions all makers are agreed that pasteurisation leads to a cleaner-flavoured product. Practically all published experiments reveal that the cheese from pasteurised milk scores significantly higher than that from the raw milk.

It should be remembered, however, that cheese-grading is a subjective matter, and that the grader, the connoisseur, the general public, and the scientist will not necessarily have the same opinion on a cheese, nor, indeed, on what is the ideal flavour to aim at.

Uniformity of product. The recent trend of marketing indicates that uniformity in a product is the most important aspect, given a reasonable standard. *Pasteurisation undoubtedly gives a much more uniform cheese irrespective of the quality of the milk.*

Increase in yield. Although a few makers report no difference in yield, most agree that a small increase is found with pasteurisation. Typical figures quoted are 4 per cent., ¼ to ½ per cent., 3 per cent., 2 to 3 per cent.

An additional factor is the lower loss in storage when the milk is pasteurised. The increased yield is chiefly due to moisture, presumed to be due to the coagulation of the albumin and globulin resulting in retention of additional moisture. For the same reason the fat losses in the whey are less. The coagulation of milk by rennet is largely a matter of the behaviour of the calcium caseinate—colloidal calcium phosphate complex. Drastic heat treatment (*e.g.* 180° to 185° F. flash) will result in loss of elasticity, weak body, and lack of coherence as the result of precipitation of the denatured albumin on the casein particles. (*See* pp. 48 and 902.)

The following objections have been raised against pasteurising milk for cheesemaking:

There is no doubt that pasteurisation results in a slow development of flavour. Flavour in cheese is, however, largely a question of marketing, *i.e.* what the public wants. Those who regret the passing of the *real* Cheddar (meaning the strong-flavoured type) cannot stop the mass of the population preferring the mild type prepared from pasteurised milk. If it is desired to make cheese having a typical Cheddar flavour from pasteurised milk there are two simple ways of attaining this end. One is to use a starter of *L. casei* with the ordinary starter. This organism is considered to confer the typical flavour in Cheddar cheese.

Another method is *not* to pasteurise a small quantity of first-quality milk (*e.g.* 5 to 10 per cent. of the total) if this can be obtained, and mix this in with the bulk of pasteurised milk.

It is generally considered that cheese from pasteurised milk takes twice as long to ripen as that from raw milk. To attain the same intensity of flavour, therefore, would require, say, six months' ripening instead of three. Such treatment would be very expensive, but, fortunately, the demand (or acceptance) by the public of mild-flavoured cheese in effect kills this objection. A considerable demand for full-flavoured cheese would, however, be a matter of concern to producers of cheese from pasteurised milk. It may also be noticed that although the flavour of such cheese is milder, it is also cleaner than that of cheese from raw milk of the usual quality delivered to cheese factories. If good-quality milk is used it will give good-flavoured cheese without pasteurisation.

It is now admitted by all competent to judge that pasteurisation does not imply that no care in production is required. Badly produced milk will still be bad (although not quite so bad) after pasteurisation. Pasteurisation, in fact, should be regarded as *a method for improving good milk and making it safe.*

There can be no question, however, that with pasteurisation reasonable quality cheese can be made from milk that would otherwise yield a very low-quality product. The writer has known of factory cheese made from milk with a count of roughly one hundred million per ml. and with coli largely responsible for the initial acid production. When milk can be produced generally with a low bacterial count and with no pathogenic micro-organisms, pasteurisation can be abandoned. Until this Utopian state of affairs is realised, pasteurisation will continue to be an extremely valuable help to the industry.

The cost naturally varies with conditions, but it may be put down at ¼d. to 1d. per gal. As a safe limit for commercial purposes it may be said that a daily gallonage of 1000 or over for cheesemaking makes it worth while to pasteurise. Smaller quantities *may* be uneconomic purely on account of the overhead costs.

The farmhouse cheesemaker should never need to have recourse to pasteurisation. Such a need would indicate extremely careless methods of production for which there is no excuse. The farmhouse-maker's chief fear is abnormal or badly contaminated milk from cows with udder disease. (*See* pp. 1 and 659.)

The temperature-time conditions of pasteurisation (whether holder, 145° F. for 30 min., or H.T.-S.T., 161° F. for 15 sec.) may be regarded as the threshold at which obvious physical and chemical changes begin to take place in the milk. Most bacteria and some enzymes are destroyed. From the cheesemaking point of view, very few deleterious effects are caused by *correct* pasteurisation. The most noticeable are a somewhat quicker rate of starter growth (acid development) and a slightly longer time of coagulation with rennet. Many cheesemakers, however, fail to notice any difference, especially with the H.T.-S.T. process. If changes are noticed, it may be advisable to use a little less starter and a little more rennet. Excess acid may lead to bitterness and crumbliness, and the most common error in using pasteurised milk is to use too much starter. It is recommended always to wait for the development of acid as against the practice of some factories of tipping in large amounts in order to " get things moving ".

More drastic heat treatment leads to lack of body and flavour, bitterness, and unduly retarded ripening.

No trouble should be experienced with making Cheddar. Minor alterations in the method may be employed (M. C. Taylor, 1937). Trouble has been experienced in America in making Domestic Swiss, but European makers have been successful in using pasteurised milk. It is with the semi-soft and soft varieties that the real failures have occurred. Many experts have proclaimed the impossibility of making really good cheese of these types from pasteurised milk. If true, this may be ascribed to the more important role of the general flora of milk and of the inherent enzymes in milk in such cheese than in hard-pressed types. *See* Cheese; Diseases; Enzymes; Heat treatment; Legal aspects; Management of pasteurising depots; Nutritive value; Phosphatase test; Routine tests; Testing milk supplies; Thermoduric bacteria; Thermophilic bacteria; Tuberculosis; Uperisation.

Refs.: Cuttell; Cronshaw; Harvey and Hill; Hill; Wilson; Farrall; Enock.

Dairy bacteriology reviews: Soc. Dairy Tech. (1953), *Pasteurising plant manual*, S.D.T., London; Jordan *et al.* (1952), *JMFT*, **15**, 155 (efficiency of holding tubes); Davis (1953), *DI*, **18**, 210 (T.B.); Davis (1953), *DI*, **18**, 682 (Control of H.T.S.T.); Galesloot (1952), *NMDJ*, **6**, 283; Kay *et al.* (1953), W.H.O. Monogr., Ser. No. 14; Murray (1952), *JSDT*, **5**, 324 (bacteriology); Alexander and Higginbottom (1953), *JDR*, **20**, 156 (bacteriology); Jordan and March (1953), *JDS*, **36**, 614 (overholding); Tobias *et al.* (1953), *JDS*, **36**, 356 (high temp.); Burton (1951), *DI*, **16**, 823; Clegg and Lomax (1951), *SAB*, **14**, 23 (" in bottle "); Anderson and Meanwell (1950), *JSFA*, **1**, 77 (bacteriology); Ashton (1950), *JDR*, **17**, 261 (bact. of H.T.-S.T.); Egdell and Bird (1950), *JSDT*, **3**, 171; Lomax and Clegg (1950), *SAB*, **13**, 1 (faults); Rowlands (1950), *JSDT*, **3**, 213 (bacteriology); Seligman (1950), *JSDT*, **3**, 224 (engineering); Stansby (1950), *DI*, **15**, 266 (milk quality); Anderson *et al.* (1949), *IDC*, **3**, 17 (K.Q.); Cuttell (1949), *JSDT*, **2**, 170 (H.T.-S.T.); Goodman (1949), *IDC*, **3**, 57 (holding in H.T.-S.T.); Anas, 531 (heat exchange); Lindqvist (1949), *IDC*, **2**, 731 (laboratory pasteuriser); Ritchie (1949), *JSDT*, **2**, 164; Pascoe (1948), *JSDT*, **1**, 259 (lab. H.T.-S.T.); Crossley and Patten (1947), *SAB*, p. 50 (distribution); Morris and Edwards (1947), *SAB*, p. 21 (colony count); Morris and Edwards (1947), *SAB*, p. 21 (high counts); Steghart (1947), *JDR*, **15**, 18 (measurement of T change in H.T.-S.T.); B.I.O.S. Report No. 770 (1946) (pasteurisation by ultra-violet light); Dahlberg (1946), *Cornell Bull.* 838 (keeping quality); Hall (1946), *JDR*, **14**, 1 (temperature control in H.T.-S.T.); Anderson and Meanwell (1949), *JRSI*, **69**, 24; Holland and Dahlberg (1940), *N.Y. Sta. Agr. Exp. Sta. Tech. Bull.*, 154; Hiscox (1944), *JSCI*, **63**, 298; Mattick and Hiscox (1939), *Med. Off.*, 6th May; Watson *et al.* (1946), *SAB*, p. 56; Davis and Watson, p. 81; Dalrymple-Champneys (1939), *The Supervision of Pasteurising Plants*, H.M.S.O.; Taylor (1937), *Proc. World's Dairy Congr.*, II, 227.

PASTEURISATION, ALTERNATIVES TO. Various treatments have been proposed from time to time as alternatives to pasteurisation. These include: (i) Hofius process (p. 503); (ii) " electronic heating " (high-frequency waves);

(iii) ultra-violet irradiation ; (iv) the so-called " electrical treatment " (bactericidal effect apparently only due to the heat produced by the electrical current) ; (v) ultrasonic vibration. The sponsors of these methods appear to imply that modern pasteurisation methods are unsatisfactory, but this is far from the truth.

It should be realised that apart from the question of licensing for such methods, pasteurisation can be easily checked by the phosphatase test, a satisfactory result indicating a safe milk.

It may be difficult to devise a simple check test for the efficiency of application of other methods, no matter how effective they are in principle.

The more important methods are briefly described below.

Electron beam treatment. High-velocity electrons, or cathode rays, are capable of destroying bacteria with high efficiency (Dunn *et al.*, 1948). Equipment has been developed by means of which very intense beams of electrons can be generated for the treatment of foodstuffs, and according to Huber the keeping time can be greatly lengthened. However, side reactions take place which may affect the palatability of the food adversely. In particular a characteristic smell develops, although this may disappear in a few days, and bleaching may occur. These difficulties can be overcome with some foods, but dairy products seem to be particularly susceptible.

Although this process is claimed to be economically sound, further investigation of the resulting side reactions is necessary before an opinion can be given on its ultimate utility.

Refs.: Dunn, Campbell, Fram and Hutchins (1948), *J. App. Phys.*, **19**, No. 7, p. 605; Huber (1948), *Electronics*, **21**, No. 3, p. 74; Proctor and Goldblith (1951), *Advances in Food Research*, Vol. III, N.Y.; Hannan (1953), *SAB*, **16**, 88.

Radio-frequency pasteurisation. This is usually taken to mean the use of radio-frequency heating for the pasteurisation of milk. Since milk is itself an electrical conductor, although a rather poor one, radio-frequency dielectric or induction heating does not occur. The mechanism is actually resistance heating, as in the case of the " Electropure " process, with the difference that the electrodes need not be in contact with the milk. Several investigators, notably Brown, Hoyler and Bierwith, have shown that milk can be satisfactorily treated by this method. Due to the rapid heating which is possible with the resistance method, higher pasteurising temperatures can be used without a deleterious effect on the milk.

However, the same economic factors apply as in the " Electropure " process (*see* p. 819) with the additional disadvantage that a radio-frequency generator is used which has an overall efficiency of only some 50 per cent. The advantages, such as the absence of contact between the electrodes and the milk, are far outweighed by the economic disadvantages.

It has been claimed that it is possible to destroy bacteria in milk, at temperatures which are normally non-lethal, by treatment with radio-frequency radiations. These claims cannot yet be substantiated.

Ref.: Brown, Hoyler and Bierwith (1947), *Theory and Applications of R.F Heating*, N.Y.; Ingram and Page (1953), *SAB*, **16**, 69.

Ultrasonic radiations. These radiations consist of pressure variations of the same type as sound waves, but of a frequency so high as to be inaudible. They can be generated either purely mechanically or electro-mechanically. In the latter case valve generators form the source of high-frequency oscillations and a transducer such as a quartz crystal or rod of magnetic material is used to convert the electrical energy to the mechanical form. These radiations have been used for homogenising milk (*see* Homogenisation) and have been suggested for pasteurisation.

Ultrasonic sterilisation. It was shown in the late nineteen-twenties that high intensity sonic and ultrasonic waves have a destructive effect on organised cells and bacteria. Application to milk treatment by Chambers and Gaines rapidly followed. A frequency of 8900 cycles per sec. was used, and the milk was passed over the surface of a vibrating nickel tube. Continuous flow experiments showed bacterial reductions of 80 per cent. on the average, with the temperature below 50° F.

Beckwith and Weaver later investigated bacteria contained in water and beef extract, and found considerable lethal effect. In milk, however, the destruction was much lower and further investigation showed that the presence of casein was responsible. Other workers have shown that protein material tends to protect bacteria from ultrasonic radiations, and that it is therefore extremely difficult to obtain satisfactory results in milk treatment.

There are other disadvantages attached to the process. All the applied ultrasonic energy appears in the form of heat in the milk. Bacteria appear to require a significant time for destruction, although the precise mechanism is not understood, and the time depends on the age and type of the organism. The resulting rise in temperature during the time of treatment may therefore be considerable. Other disadvantages are that ultrasonic energy can only be generated at powers of below about 1 kilowatt, and that the first costs and running costs of the equipment are high.

Application of this method of milk pasteurisation outside the research laboratory is unlikely.

Refs.: Chambers and Gaines (1932), *MD*, **21**, No. 7, p. 40; Beckwith and Weaver (1936), *JB*, **32**, p. 361. Jacobs and Thornley (1954), *SAB*, **17**, 38.

Ultra-violet radiations. Ultra-violet radiations constitute a part of the electro-magnetic spectrum. They occupy the region of wavelengths immediately shorter than the blue end of the visible spectrum, which has a wavelength of about 4000 Ångstrom units (4×10^{-7} m.). The lower limit of the ultra-violet spectrum has a wavelength of about 200 Å. (2×10^{-8} m.) (*see* Fig. PA 1).

These radiations are significant in dairying because they are capable of

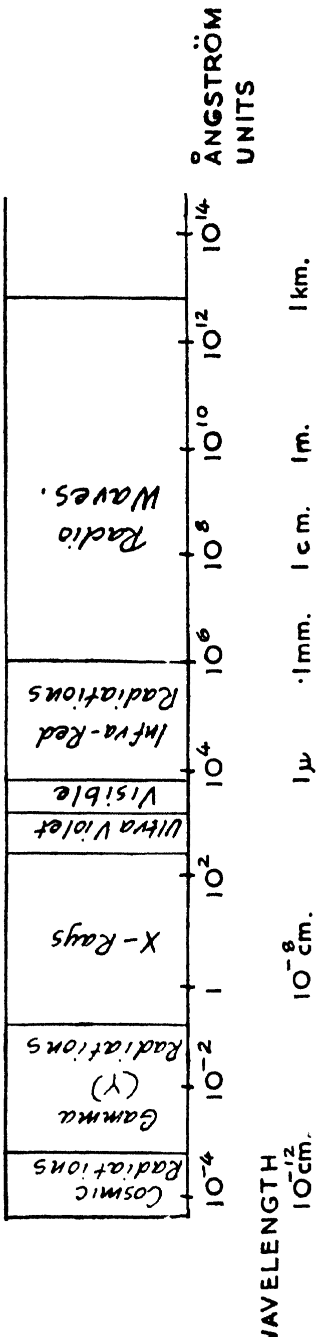


FIG. PA 1.—*The Electromagnetic Wave Spectrum.*

being absorbed by certain organic compounds, and thus of bringing about photo-chemical reactions. Examples of such reactions are the destruction of bacteria by ultraviolet radiations having wavelengths of about 2600 Å. ($2{\cdot}6 \times 10^{-7}$ m.), and the conversion of ergosterol and 7-dehydrocholesterol to vitamin D by radiations of 2700 to 2900 Å. ($2{\cdot}7$ to $2{\cdot}9 \times 10^{-7}$ m.) wavelength. *See* Vitamins.

Ultra-violet sterilisation. It has been known since 1892 that ultra-violet radiations are capable of destroying bacteria. Much work has been carried out since then to determine how the effect varies with wavelength, and it has been shown that the greatest lethal action is given by wavelengths of about 2600 Å. The relation between bactericidal effectiveness and wavelength is as shown in Fig. PA 2.

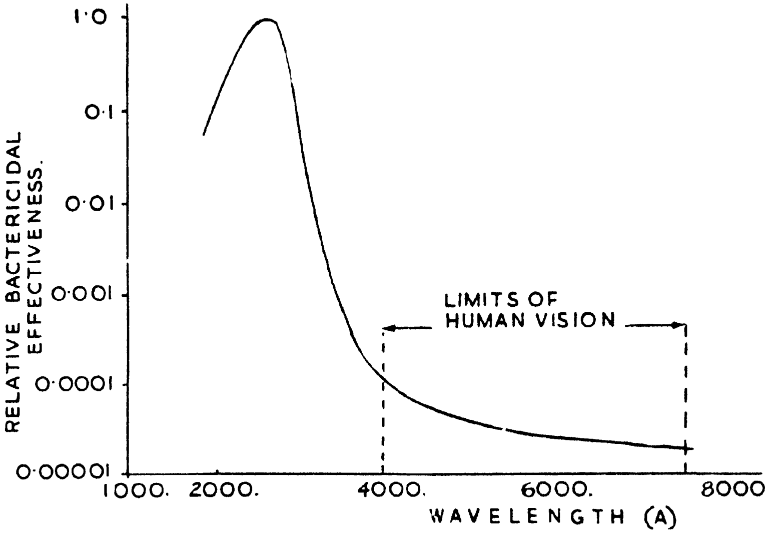


FIG. PA 2.—*Variation of Bactericidal Effectiveness of Ultra-violet Radiation with Wavelength.*

The destruction of bacteria is exponential with respect to time when a constant intensity of radiation is applied. The total kill depends upon the amount of energy supplied, *i.e.* the product of the intensity of radiation and the time of application.

Since early in the century many attempts have been made to apply ultra-violet radiations to the sterilisation of milk. These have met with varying success, but it is not until recent years that equipments have been built which appear capable of giving consistent results comparable with those of heat pasteurisation.

Two major technical problems have had to be overcome in the development of equipment. The first is the difficulty of subjecting the whole of a mass of milk to the radiations in view of the low penetration of ultra-violet radiations into milk. The intensity of the radiations decreases exponentially from the surface into the body of the milk. The effective penetration at different wavelengths, defined as the depth which, when multiplied by the full surface intensity, gives the total integrated intensity for the exponential curve, is given in Table PA 1. It can be seen that bactericidal radiations have a penetration of less than 1/20 mm. In spite of this limitation it is necessary for every part of the milk to be irradiated if a sufficiently high kill is to be maintained.

One of the most popular ways of approaching this problem has been to cause the milk to flow in a film sufficiently thin for the radiations to be able to penetrate it. The milk has been made to flow over corrugated surfaces or revolving horizontal rollers, or inside vertical rotating vessels under centrifugal action. Difficulties have been met with, however, in obtaining and maintaining a sufficiently stable film.

TABLE PA I

VARIATION OF EFFECTIVE PENETRATION OF U.V. RADIATIONS INTO MILK WITH WAVELENGTH

Wavelength A	*Effective penetration (mm.)*
2500	0·036
2750	0·038
3000	0·041
4000	0·050
5000	0·058
6000	0·065
7000	0·073
8000	0·080

In another method, the milk is pumped at high velocity through a series of quartz tubes, quartz being transparent to radiations in the ultra-violet spectrum. If the velocity and the dimensions of the tube are correctly arranged to give a high Reynolds number, a considerable degree of turbulence exists in the milk flow. After the milk has passed through a sufficient length of tube, all parts of it should have come under the influence of the radiations.

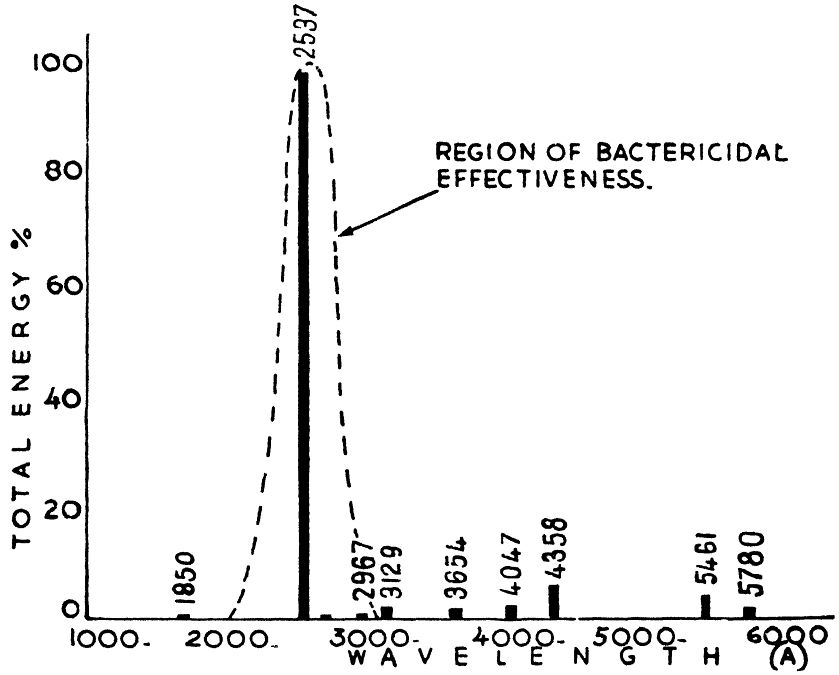


FIG. PA 3.—*Spectrum of the Low-Pressure Mercury-Vapour Discharge.*

The second problem referred to is the production of taints due to irradiation. Ultra-violet radiations with wavelengths of less than 2000 Å. have the property of forming ozone from atmospheric oxygen, while the wavelength 1850 Å. seems to be particularly active in this respect. If milk is irradiated in contact with air, great care has to be taken to prevent the formation of these taints. In the case of the equipment mentioned above in which the milk is contained in quartz tubes, contact with atmospheric oxygen and ozone is avoided, but it is not clear whether the action of the radiation on the air dissolved in the milk has any effect. Precautions can alternatively be taken against the production of 1850 Å. radiation.

A convenient source of ultra-violet is the low-pressure mercury-vapour discharge lamp. A spectrum of this type of lamp is shown in Fig. PA 3. It can be seen that more than 95 per cent. of the total output of the lamp is at a wavelength of 2537 Å., and the bactericidal efficiency is therefore high. A small amount of energy at 1850 Å. is developed, and is radiated if the lamp envelope is of quartz. This is sufficient to form ozone from atmospheric oxygen, and precautions against tainting of the milk then have to be taken as described above. By using a lamp envelope of specially prepared glass, the 1850 Å. radiation can be suppressed, although most of the 2357 Å. radiation is transmitted. Ozone production is thus eliminated.

A further method of suppressing the 1850 Å. radiation is to use a high-pressure mercury-vapour discharge in which vapour pressures of over ten atmospheres are obtained. With this type of lamp, the shorter wavelength ultra-violet radiations are not generated, but a more continuous spectrum is obtained in the long-wave ultra-violet and visible regions. Although ozone production is avoided, the bactericidal efficiency of the lamp is lower than that of the low-pressure discharge, since much more of the energy is transmitted as bactericidally-ineffective long wave radiations.

Irradiation of milk appears to have no effect on its digestibility and nutritive properties, or on the content of vitamins A and B, riboflavin and carotene. There is some loss of vitamin C, but the vitamin D content is considerably increased (*see* Vitamins).

A plant for ultra-violet pasteurisation of milk constructed in Germany has been described by Capstick, Hall and Neave. Very interesting results were obtained with tests on the equipment, and in some cases a reduction in bacterial count greater than that given by laboratory heat pasteurisation was obtained. More recently kills of greater than 99 per cent. have been claimed for a variety of organisms with a plant of this type.

It is not possible at the moment to give figures of the cost for an ultra-violet radiation pasteuriser, assuming that an entirely satisfactory equipment suitable for commercial application can be developed. There are too many as yet undetermined factors which would need to be taken into account.

Refs.: Luckeish (1946), *Applications of Germicidal, Erythemal and Infra-red Energy*, N.Y.; Capstick, Hall and Neave, B.I.O.S. Report No. 770; Burton (1951), *DSA*, **13**, 229; Burgess and Herrington (1953), *JDS*, **36**, 563.

X-ray treatment. X-rays are electromagnetic radiations having wavelengths shorter than ultra-violet radiations (*see* Fig. PA 1). A comprehensive account of their bactericidal properties has been given by Lea (1946). It has also been shown that milk can be sterilised by X-radiation if applied in sufficient dose, and that the taste is not affected (Dunn *et al.*, 1948). Even with very high voltage equipment the time of treatment is over 30 min. In view of the time factor and the complex equipment required, it is difficult to envisage this method of treatment ever being a practical one. *See* Pasteurisation.

Refs.: Lea (1946), *Actions of Radiations on Living Cells*, Cambridge; Dunn, Campbell, Fram and Hutchins (1948), *J. App. Phys.*, **19**, 605.

PASTEURISED MILK, DETECTION IN RAW MILK. It is impossible to estimate the amount of pasteurised milk added to raw milk. Suggestive evidence can be obtained by estimating the proportion of albumin and globulin denatured, and the contents and ratios of the various enzymes.

PASTURE. Land down to grass which is used for grazing; a *meadow* is reserved for hay. *See* Agriculture; Feeding; Grassland; Management of dairy cattle.

PELLICLE. The skin formed on the surface of nutrient liquid media by certain micro-organisms. It is of some diagnostic value.

PENICILLIN. A group of antibiotics (p. 55) produced by *Penicillium notatum* and other species. Highly promising results have been obtained in the treatment of mastitis. However, penicillin treatment may easily lead to trouble in cheese making (p. 168) by causing slow starter (p. 977). Penicillin can also have an effect on the methylene blue test and keeping quality of milk. *See* Antibiotics.

Refs.: Smith; Wilson and Miles; Hunter (1949), *JDR*, **16,** 39 (p. on lactic streptococci); Rowlands (1951), *SAB*, **14,** 7 (MB and K.Q.).

PENICILLIUM. One of the commonest moulds, usually green in colour. *P. roqueforti* is responsible for the blue veins in Stilton and similar cheese. *See* Cheese, p. 168; Moulds.

PEPSIN. *See* Enzymes.

PEPTONES. This word is used in two senses: (i) a dried peptic digest of fibrin, casein, etc., used as a base for bacteriological media; (ii) degradation products of a certain size in the enzymic breakdown of proteins. *See* Enzymes; Media; Protein degradation products.

PERMANENT PASTURE. A pasture which is not ploughed up at intervals. *See* Agriculture; Feeding; Grass; Pasture.

PERMANENT PIPE LINES. *See* Pipelines.

Refs.: Alexander *et al.* (1952), *JDS*, **35,** 874.

PECORINO. *See* Cheese, p. 198.

PEROXIDASE. A heat-resistant enzyme catalysing the oxidation of substances in the presence of hydrogen peroxide. It is present in milk and especially in abnormal milk (p. 1). Peroxidase is readily detected by the blueing of guaiaconic acid in the presence of hydrogen peroxide. This colour reaction is known as *Storch's reaction* and is used as a test for heated milk on the Continent. Peroxidase in milk is destroyed at 70° C. in 150 min., at 74° in 6 min., at 76° in 1½ min., and at 78° in 15 sec. *See* Enzymes.

Ref.: Roth (1949), *M*, **4,** 18, 47, 80 (inhibition).

PERSIA. *See* Iran.

PETTENKOFER'S TEST. A spot test for the presence of bile. The substance is moistened with a little sugar solution, dried, and treated with sulphuric acid. If bile is present a red colour develops.

PHASE. (i) In physics and chemistry a phase may be defined as a portion of gas, liquid or solid, which is distinct from another portion and separated by a well-defined boundary. Thus in milk the air over it constitutes one phase, and the fat globules another phase; if souring precipitates the casein, this solid protein constitutes another phase.

Refs.: Adam; Clayton; Rogers.

(ii) In bacteriology the term phase is used to describe the progressive stages in the growth of bacteria: (*a*) the lag phase; (*b*) the logarithmic growth phase; (*c*) the stationary phase; (*d*) the dying-off phase.

Refs.: Buchanan and Fulmer; Wilson and Miles.

PHASE CONTRAST. *See* Microscope.

PHASE INVERSION. Milk is an emulsion of fat in milk serum; butter an emulsion of milk serum in fat. The change of cream into butter is generally termed " phase inversion ', *i.e.* the emulsion of fat in water becomes an emulsion of water in fat. *See* Butter.

Ref.: Clayton.

pH. *See* Acidity; Buffers; Buffer value; Hydrogen ion concentration; Media; Quinhydrone electrode.

PHOSPHATASE TEST. This test (Kay and Graham (1935), *JDR*, **6**, 191) depends on the detection of the enzyme phosphatase, which is always present in raw milk but is destroyed by the time-temperature combination necessary for efficient pasteurisation. The absence of phosphatase indicates that the milk has been adequately heated, while its presence points to insufficient heating or to contamination with raw milk.

When milk containing phosphatase is incubated with disodium phenyl phosphate, free phenol is liberated in a quantity which is an approximate measure of the phosphatase present. The phenol is determined colorimetrically.

Reagents required. (1) A buffer-substrate solution containing disodium phenyl phosphate buffered with sodium barbiturate. The solution is saturated with chloroform and kept in a refrigerator. Tablets sufficient for 50 ml. of solution are available.

(2) Folin's and Ciocalteu's phenol reagent, diluted to three times its volume before use.

(3) A 14 per cent. solution of sodium carbonate.

Carrying out the test under standard conditions produces a pale blue colour which, in the absence of phosphatase, does not exceed a certain value. Instruments are available for measuring the intensity of the colour (Lovibond comparator, British Drug Houses, Ltd., Graham Street, City Road, N.1). Two tests, A and B, are carried out. The shorter test (A) can be carried out in 30 min., and is used to determine whether milk has been heated or not, or for observing gross errors in the process of pasteurisation. Test B is used for determining small as well as large errors in processing, and requires 24 hr. to carry out.

Test A. 0·5 ml. of milk is incubated at 47° ± 2° C. for 10 min. with 10 ml. of buffer-substrate solution in a 25 ml. test-tube. After cooling (15° to 20° C.), 4·5 ml. of the Folin phenol reagent are added, allowed to stand for 3 min. and filtered. To 10 ml. of the filtrate immediately after filtration are added 2 ml. of sodium carbonate solution, and, after mixing, placed in boiling water for 5 min. and then, after cooling, filtered into a special tube which is placed in the colorimeter and the colour compared with those of the standard glasses.

The test should be carried out in duplicate, and controls should be carried out by adding 0·5 ml. of milk to the mixed substrate and Folin reagent, filtering and carrying on from that point as in the proper test.

If only a faint blue develops, the milk has been heated. If the controls show more than a trace of blue colour and the reagents contain no phenol, probably the milk contains a phenol-producing organism, which does not occur in pasteurised milk kept at a low temperature after pasteurisation. If the incubated tests show over 2 3 units of blue colour, the milk has not been adequately pasteurised ; if the colour is over 6·0 blue units, the milk has very probably not been heated at all. In cases where the colour produced approaches very near to the standard tint, Test B should be carried out.

Test B. The same amount of substrate and milk with two drops of chloroform are incubated at 38° C. for 24 hr., and thence as in Test A. The test is done in duplicate, and controls are run in a parallel manner either as in Test A or the filtrate from the Folin reagent is kept in a refrigerator until the next day.

The second filtration process can be avoided by adding sodium hexametaphosphate to the Folin and Ciocalteu reagents as follows : Add one volume of the stock reagent to two volumes of a 5 per cent. sodium hexametaphosphate solution and use in place of reagent (2) above. Proceed as usual, but after the addition of 2·0 ml. of carbonate solution, place in boiling water for 2 min. only, cool, and, without filtering, make the colour comparison. A simple box type comparator suitable for routine tests has been described by Herschdörfer and Neave (1937, *JSCI*, **16**, *T*, 78) and Anderson, Herschdörfer and Neave (1937, *A*, **62**, 86) have made a number of observations and useful recommendations with regard to the phosphatase test.

If the colour produced exceeds 2·3 units, the milk has been improperly pasteurised, *i.e.* the temperature of pasteurisation has been too low (by 1·5° F.) or the duration of heating at the pasteurisation temperature has been too short (20 instead of 30 min.), or raw milk has entered the pasteurised sample (at least 0·2 per cent.).

The test indicates the proper pasteurisation of milk by the holder method, *i.e.* 145° F. for 30 min. The test may also be applied to milk heated for about 18 sec. at 160° F. (*see* Kay, Aschaffenburg and Neave (1939), *Tech. Com. Imp. Bur. Dairy Sci.*, No. 1) or for 15 sec. at 161° F.

The phosphatase test has proved invaluable in the control of pasteurised milk but it is a sensitive test and requires great care in technique. The tendency is always for a positive result to be obtained wrongly due to the ease with which minute traces of phenolic substances can produce a blue colour with the reagent. Statutory Instrument No. 1589 (1949) (pp. 9 to 12) describes in detail the necessary precautions to be observed. In particular it emphasises that: (*a*) phenols, disinfectants containing phenols, and soap containing carbolic acid must be kept at a safe distance from the test reagents and apparatus; (*b*) the use of bottle caps made from phenolic resins must be avoided; (*c*) rubber stoppers may contain phenolic impurities and fresh batches must, therefore, be tested before use; (*d*) all glassware must be carefully cleaned and rinsed thoroughly before use. Cleaning in chromic acid is strongly recommended; (*e*) contamination of pipettes, etc., by saliva, which is known to contain considerable amounts of phosphatase, must be avoided; (*f*) a fresh pipette must be used for each sample of milk in order to avoid contamination by raw or insufficiently heated milk; (*g*) all reagents must be kept in a dark, cool place and well protected from dust; (*h*) tests must not be carried out in direct sunlight; (*i*) freshly boiled distilled water must be used throughout.

The preparation of solutions and technique are as follows:

Buffer-substrate. Dissolve 1·09 g. of disodium phenyl phosphate and 11·54 g. of " sodium veronal " (sodium diethyl barbiturate) in distilled water saturated with chloroform and make up to 1 l. Alternatively, use buffer-substrate tablets. Either dissolve one tablet in 50 ml. of distilled water saturated with chloroform, or alternatively, add one tablet to about 45 ml. of boiling distilled water, boil the solution for exactly 1 min., cool rapidly and make up to 50 ml. with boiled distilled water. Add a few drops of chloroform to prevent the growth of microorganisms, and keep in the refrigerator. Solutions should be discarded after 3 days.

Folin and Ciocalteu's phenol reagent (stock). Dissolve 100 g. of sodium tungstate $Na_2WO_4 . 2H_2O$, and 25 g. of sodium molybdate, $Na_2MoO_4 . 2H_2O$, in 700 ml. of water in a 1500 ml. flask connected, preferably by a ground glass joint, with a reflux condenser. Add 50 ml. of syrupy (85 per cent.) phosphoric acid and 100 ml. of concentrated hydrochloric acid. Reflux the mixture gently for 10 hr. (If an all-glass connection between flask and condenser is not available, use a rubber stopper or cork wrapped in tin foil. Take the greatest care that the solution does not come in contact with the tin foil.) After 10 hr., cool, add 150 g. of pure lithium sulphate, 50 ml. of water and a few drops (usually 4 to 6) of liquid bromine and leave for 2 hr. Then boil the mixture under the hood without the condenser for 15 min. to get rid of excess bromine. Cool, dilute to 1 l. and filter. The finished reagent should have a golden yellow colour with no greenish tint. Any reagent with a greenish tint should be rejected. Keep in a refrigerator and protected from contact with dust, metal, etc., and any reducing substance. The reagent is usually quite stable for at least 4 months.

Sodium hexametaphosphate. Use the salt in the form of flakes and sift in order to remove any white powder which has formed during storage. Always keep in a tightly stoppered bottle. Prepare a 5 per cent. solution (weight per volume) by dissolving in warm water and making up to volume after cooling.

PHOSPHATASE TEST

Test reagent. Add 1 volume of the stock solution of Folin and Ciocalteu's reagent to 2 volumes of the hexametaphosphate solution. The mixture is stable for several weeks.

Sodium carbonate. Make up a 14 per cent. solution (weight per volume) of pure anhydrous sodium carbonate. It is advisable to standardise this solution by titration.

Apparatus. (*a*) a water bath or incubator maintained at 37 ± 1° C.; (*b*) a graduated pipette or an automatic burette to deliver 4·5 ml. The latter should be made from dark glass or should be painted a dark colour; (*c*) a number of grade A 1·0 ml. straight sided pipettes, accurately marked at 0·5 and 1·0 ml. These should be plugged with cotton wool; (*d*) a number of test tubes conforming to British Standard Specification No. 625 (1935), 152/16, accurately marked at 10 ml., with rubber stoppers to fit. Before use these test tubes should be cleaned in chromic acid; (*e*) a number of filter funnels, 5 cm. diameter; (*f*) Whatman filter papers, 9 cm. No. 40; (*g*) either a Lovibond comparator with cell marked at 25 mm. and with disc containing standard coloured glasses corresponding to 0·5, 1·5, 2·3 and 6·0 Lovibond blue units, or a Lovibond tintometer with 13 mm. cell.

Determination. Tests should always be carried out in duplicate. To 10 ml. of the buffer-substrate solution contained in a test tube, add 0·5 ml. of the well-mixed milk. Add 3 drops of chloroform, stopper the tube, mix the contents, and incubate at 37 ± 1° C. for 24 ± 2 hr. At the end of this time, cool, add 4·5 ml. of the test reagent, mix, allow to stand for 3 min., and filter into a test tube marked at 10 ml. To 10 ml. of the filtrate add 2 ml. of the sodium carbonate solution, mix and place test tube for exactly 2 min. in boiling water (kept boiling). Cool and proceed to read the colour thus developed, using either the comparator or the tintometer.

Control tests. Keep all milk samples in the refrigerator for 24 hr. after the duplicate experimental tubes have been put into the incubator. *After completing the test proper* carry out control tests on those samples which have given a positive phosphatase reaction.

Proceed as follows: mix thoroughly 10 ml. of the buffer-substrate solution with 4·5 ml. of the test reagent, add 0·5 ml. of milk and mix. Allow to stand for 3 min., and filter into a test tube marked at 10 ml. To 10 ml. of the filtrate, add 2 ml. of the sodium carbonate solution, mix and place the tube for exactly 2 min. in a boiling water bath (kept boiling). Cool and proceed to read the colour thus developed. The colour should not exceed 1·5 Lovibond blue units.

Test of reagents. To test the purity of the reagents, a blank test should be carried out by incubating a tube containing buffer-substrate and chloroform, but *no* milk, with each batch of samples. The colour should not exceed 0·5 Lovibond blue units.

Interpretation. Milks which give readings of 2·3 Lovibond blue units or less should be classified as "giving a negative phosphatase test" or as "sufficiently heat treated", those giving readings between 2·4 and 6·0 Lovibond blue units as "insufficiently heat treated", whilst those giving readings greater than 6·0 Lovibond blue units should be reported as "grossly undertreated". Raw milk gives more than 30 Lovibond blue units. If a positive phosphatase test, *i.e.* a reading of more than 2·3 Lovibond blue units, is obtained it is not possible on the basis of this finding alone to decide whether the cause is too low a temperature or too short a holding time, or the addition of raw milk.

Aschaffenburg and Mullen (*JDR*, 1948, **16**, 58) have described a simple modification of the phosphatase test which permits the detection of under-pasteurised milk in ½ hr. It depends on the hydrolysis of para-dinitrophenol phosphate to give the nitro phenol which gives a yellow colour in milk. Aschaffenburg (1953, *DI*, **18**, 316) has described a simple Na_2CO_3—$NaHCO_3$ buffer for this form of the test.

The American methods (*AOAC* ; *SMDP*) are based on the formation of more than 0·047 mg. phenol by 0·5 ml. milk but it should be remembered that American requirements for pasteurisation are less stringent than ours (*e.g.* 143° F. for 30 min. or 160° F. for 15 sec.) and therefore more phosphatase will be left in the milk.

The writer is of the opinion that it might have been better to have standardised the routine control method on a control basis, *i.e.* the difference between incubated and unincubated control tests. The latter usually gives a value of 1·0 to 1·5 L.B.U. so that a standard of 1 L.B.U. *increase* over the control would correspond to the original *absolute* standard of 2·3 L.B.U. In the early days of the phosphatase test many false positives were undoubtedly returned, largely because of the ease with which false positives can be obtained. Even to-day (1954) although the technique is now generally satisfactory, occasional mysteries occur, and the following procedure is recommended:

The test in its statutory form should be regarded as a sorting or screening test. Whenever a positive is obtained, the sample (which should have been kept overnight in the refrigerator) should be tested as follows:—

(i) repeat the test;
(ii) make an unincubated control test;
(iii) re-pasteurise the sample (35 min. at 145-146° F.) and test;
(iv) make an Aschaffenburg and Mullen test (2 hr.).

If (i) and (iv) are positive and (ii) and (iii) are negative, the first positive result can be regarded as completely confirmed (Davis (1954), *DI*, **19**, 383).

Reactivation. It has been observed that in milk heated momentarily to 130-150° C. (*see* Uperisation) the phosphatase may be re-activated after a few days' storage (Wright and Tramer (1953), *JDR*, **20**, 117, 258). This effect is detectable in milks heated up to 170-180° C. for 15 sec., and the best temperature for reactivation is 30° C. A similar effect is noticeable with cream (Ritter (1953), *DC*, **3**, 1014). Reactivation can occur with HT-ST or Vacreator treated but not with holder pasteurised cream.

See Enzymes ; Legal aspects ; Pasteurisation.

Refs.: Milk Testing: Richmond; Cook and Hughes (1953), *DI*, **18**, 43 (errors); Tramer (1952), *JDR*, **19**, 275; Wright and Tramer (1952), *DI*, **17**, 54; Kay *et al.* (1949), *IDC*, **2**, 743 ; Sjostrom, 750 ; Sanders, 757 ; Andersen, 766 ; Kosikowsky (1951), *JDS*, **34**, 1151 (simple universal ("Cornell") test); Mullen (1950), *JDR*, **17**, 306 (acid phosphatase); Tramer and Wright (1950), *JDR*, **17**, 194 (discs); Aschaffenburg and Mullen (1949), *JDR*, **16**, 58 (new rapid test); Ludlam and Hemingway (1950), *MBMH*, **9**, 280; Andersen (1949), *IDC*, **3**, 90; Stiven (1947), *JDR*, **15**, 57 (simple "screening" test); Neave (1939), *JDR*, **10**, 474 (use of hexametaphosphate and other technique factors); Aschaffenburg and Neave (1939), *JDR*, **10**, 485 (rapid test and reliability aspects); Kay and Graham (1933), *JDR*, **5**, 63 (original paper).

PHOSPHATASES, BACTERIAL.

Ref.: Tramer (1952), *JDR*, **19**, 275.

PHOSPHATES. Phosphates are quantitatively the most important anion in milk, although citric acid is present to almost the same amount and the chlorides exercise a greater effect on the osmotic pressure or freezing-point depression on account of their lower molecular weight. Moreover, some phosphate is linked with the casein as an " insoluble phosphate " and phosphorus is also an integral part of the casein molecule. Phosphate, as a poly-basic radicle, plays a large part in the heat stability of milk, especially in condensing (p. 277). *See* Constituents.

Ref.: Pyne and Ryan (1950), *JDR*, **17**, 200 (colloidal).

PHOSPHATIDES, PHOSPHOLIPOIDS. These complex organic compounds are mixed esters containing glycerol, choline, phosphoric acid or amino-ethyl phosphoric acid and higher fatty acids. The phosphatides or phospholipids are easily destroyed by heat and oxidation and are, in virtue of this fact, an important factor in the auto-oxidation of milk fat and the development of taints such as " oiliness " and " cardboard flavour ". *See* Auto-oxidation; Flavours; Milk powder.

Refs.: Davies; Richmond; Rogers; Wittcoff (1951), *The Phosphatides;* Mohr (1950), *N*, **5**, 121.

PHOSPHOLIPIDS. *See* Phosphatides.

PHOSPHORUS. An inorganic element present in relatively large amounts in milk and also in brain and bone marrow.

In milk it is present (i) as inorganic phosphates (soluble and insoluble); (ii) as organic phosphates; (iii) in the casein molecule.

PHYSICS. The study of energy and matter.

Refs.: Rogers; Richmond; Rahn and Sharp (1928), *Dairy Physics* (in German), Berlin; Scott Blair (1952), *JDR*, **19**, 257 (review).

PHYSIOLOGY OF DAIRY CATTLE. The advances in various aspects of this subject are described in the following reviews:

Peskett (1932), *JDR*, **4**, 154 (growth); Stirling (1932), *JDR*, **4**, 156 (lactation); Morris and Mackintosh (1932), *JDR*, **4**, 163 (nutrition); Smith, A. D. B. and Robison (1932), *JDR*, **4**, 170 (genetics); Blackwood (1935), *JDR*, **6**, 252 (reproduction and lactation); Morris (1935), *JDR*, **6**, 260 (nutrition); Smith, A. D. B. (1935), *JDR*, **6**, 272 (genetics); Smith, J. A. B. (1937), *JDR*, **8**, 105 (reproduction and lactation); Morris (1937), *JDR*, **8**, 119 (nutrition); Smith, A. D. B. (1937), *JDR*, **8**, 131 (genetics); Smith, J. A. B. (1939), *JDR*, **10**, 133 (reproduction and lactation); Morris (1939), *JDR*, **10**, 153 (nutrition); Smith, A. D. B. (1939), *JDR*, **10**, 370 (genetics); Smith, J. A. B. (1941), *JDR*, **12**, 78 (reproduction and lactation); Owen (1941), *JDR*, **12**, 213 (nutrition); Smith, J. A. B. (1945), *JDR*, **14**, 195 (reproduction and lactation); Owen (1947), *JDR*, **15**, 142 (nutrition); Smith (1950), *JDR*, **17**, 338; Owen (1951), *JDR*, **18**, 113; Smith (1953), *JDR*, **20**, 224 (reproduction and lactation).

See Digestion in the ruminant; Glands; Hormones; Milk secretion.

Refs.: Dukes (1947), *Physiology of Domestic Animals*, N.Y.; Marshall and Halnan (1946), *Physiology of Farm Animals*, London.

PHYTOSTEROL. The common sterol present in vegetable fats, analogous to and isomeric with cholesterol in animal fats and milk. The two sterols can be differentiated by crystalline form, melting-points, and optical rotations. The difference in the melting points of their acetates forms the basis of a test for the adulteration of butter (Steuart, *A* (1923), **48**, 155; Hawley (1933), **58**, 529).

PIGS. The satisfactory disposal of a dairy by-product is often fundamental to the economy of a dairy enterprise. Dairying is traditionally associated with pig-keeping since the pig can convert dairy by-products into valuable foods for human consumption. Although there are other methods of utilising dairy by-products the feeding to pigs still remains, under many conditions, the most economical and satisfactory proposition.

Besides being uneconomical whole milk cannot be spared for feeding to pigs, since all the available supplies are required for direct human consumption. It is, however, interesting to note that experiments carried out at Shinfield 20 years ago showed that feeding as little as ½ pint of full-cream fresh milk to pigs daily produced a marked improvement in the rate of growth, even when the basal ration was a balanced one, containing the protein, sugar and ash constituents of milk in abundance. The fresh milk appeared to supply some extra factor or factors. Other trials have shown that by feeding 4 pints of whole milk daily, the growth rate of pigs can be increased by as much as 40 per cent.

The principal dairy by-products, such as skim-milk, buttermilk and whey have a high nutritive value. To appreciate their feeding value the extent of compositional changes due to the processing of the original milk has to be known. Table Pi I gives useful information on this point. As far as the vitamins are concerned it is important to keep in mind that, generally speaking, vitamins A and D, which are associated with the fat in the milk, will not be present in the by-products.

The problem of feeding dairy by-products to pigs has two aspects : In countries where the by-products are scarce, the minimum amounts which can be fed advantageously as a supplement need to be known. In other countries, where the by-products are in abundant supply there is the problem of the maximum amounts which will give satisfactory results.

TABLE Pi I

COMPOSITION OF VARIOUS DAIRY PRODUCTS USED IN PIG FEEDING

(*Most of these values are taken from* H. E. Woodman, *Min. of Agric. Bull.* No. 124, 1944)

	Moisture	*Protein*	*Fat*	*Carbo-hydrate*	*Ash*
Whole milk (cows)	87·2	3·4	3·9	4·8	0·8
Skimmed milk, deep set . .	90·3	3·5	0·4	5·0	0·8
Skimmed milk, shallow set . .	90·0	3·5	0·7	5·0	0·8
Separated milk	90·6	3·5	0·1	5·0	0·8
Buttermilk	90·2	3·6	0·8	4·1	0·7
Whey, whole milk cheese . .	93·4	0·7	0·2	5·0	0·7
Whey, separated milk cheese . .	93·6	0·7	—	5·0	0·7
Dried casein	13·0	73·0	0·3	6·0	7·7
Dried separated milk . . .	10·3	32·8	1·5	47·9	7·5
Dried buttermilk	10·0	35·3	7·0	40·0	7·7
Dried whey	7·8	12·6	1·4	70·5	7·7
Whey paste	54·0	6·2	0·8	35·0	4·0
Whey extract (after extraction of lactose)	43·0	15·0	—	30·0	12·0

When pigs are born they rely entirely on their mother's milk for about 3 weeks to cover their requirement for nutrients. At this stage the pigs grow very rapidly, they double their birth weight in about 7 days. The knowledge of the composition of sow's milk which makes this rapid growth possible is of great interest. It is also helpful when baby pigs have to be reared on artificial diet because of death of the sow or her failure to supply a sufficient quantity of milk. Table Pi II

TABLE Pi II

COMPOSITION OF SOW'S COLOSTRUM AND MILK

(According to R. Braude *et al.* (1947), *Brit. J. Nutrit.*, **1**, 65, and unpublished data)

	Colostrum	*Milk*
Fat	4·1 g./100 g.	8·3 g./100 g.
Protein	17·8 g./100 g.	5·8 g./100 g.
Lactose	3·5 g./100 g.	4·8 g./100 g.
Ash	0·6 g./100 g.	0·9 g./100 g.
Ca	0·05 g./100 g.	0·25 g./100 g.
P	0·08 g./100 g.	0·17 g./100 g.
Vitamin A	71·1 I.U./g. fat	11·0 I.U./g. fat
Vitamin D		0·55 I.U./g. fat
Ascorbic acid . . .	30·1 mg./100 ml.	13·0 mg./100 ml.
Aneurin	96·8 μg./100 ml.	67·7 μg./100 ml.
Riboflavin	135·0 μg./100 ml.	137·0 μg./100 ml.
Nicotinic acid . . .	165·0 μg./100 ml.	836·0 μg./100 ml.
Pantothenic acid . . .	130·0 μg./100 ml.	427·0 μg./100 ml.
Pyridoxin	2·5 μg./100 ml.	20·0 μg./100 ml.
Biotin	5·3 μg./100 ml.	1·4 μg./100 ml.
Vitamin B_{12}	0·15 μg./100 ml.	0·17 μg./100 ml.

gives the main details, from which it is obvious that sow's milk resembles that of the goat or the ewe rather than that of the cow. The differences between colostrum and milk are also indicated in the table.

Collins *et al.* (1951, *J. Nutrit.*, **43,** 313) have reported the folic acid content of sow's milk to be 0·39 μg./100 ml.

Good results have been obtained by rearing piglets on cow's milk enriched with cream so that the fat content is 8 to 10 per cent. Each piglet should receive 1-2 oz. every hour for the first 2 days. Later ordinary cow's milk and eventually skim-milk may be given. Goat's milk can be fed unaltered. If at all possible, the piglets should start on sow's colostrum.

Sows will normally produce two litters annually (average gestation length is 114 days), and their lactation period should last 8 weeks on each occasion. There is very little information available on the milk yield of the sow and factors affecting it. However, the few figures found in the literature indicate that the lactation yield of a normal sow ranges from 150 to 220 kg. or about 33 to 48 gal. A breeding sow should have at least 12 teats. Each udder acts as a separate unit, and therefore the total amount of milk depends on the number of teats which are functioning, and that, in turn, is influenced by the number of piglets suckling.

It is interesting that very soon after birth the piglets, on their own accord, start suckling, and within a matter of days settle down to their particular teats for the rest of lactation and hardly ever change them. Udders which are not suckled stop functioning and dry off within a day or two. Sows and piglets are very regular in their suckling habits, the suckling taking place every 1 to 1¼ hr. throughout the lactation. Each time the actual suckling lasts 15 to 30 sec., and the yield of milk per teat may vary from 0 to 75 ml. When the litter is 14 to 21 days old, solid food should be introduced. From that time onward the nutrients supplied in the sow's milk are not sufficient to cover the requirements of the rapidly growing litter. They should be supplemented by a suckling pig's meal mixture or nuts which to be really good should contain dairy by-products as one of their ingredients.

In the past it was very difficult to obtain samples of sow's milk for investigational purposes. The sow was a complete master of her letting down of milk mechanism, and she refused to give her milk when milked by hand. Recently, however, a new method has been developed whereby through an injection of a hormone of the posterior pituitary gland, oxytocin, into the blood stream (usually ear vein) of a sow, one can completely master the let-down mechanism, and a sow can be milked either by hand or by machine. The first successful milking machine for sows has recently been reported from New Zealand by Whittlestone and Allen (*JDR* (1951), **18,** 31). After injection of oxytocin the milk flow starts within 6-12 sec., and it continues for a time, governed by the dose of the hormone. Recently, Braude and Mitchell (1950, *N*, **165,** 937) studied on sows the dose response to oxytocin and reported values covering the range from 1/100 to 20 units of "Pitocin" (a Parke Davis & Co. preparation of oxytocin). As an illustration it may be mentioned that the average responses to 1, 5 or 10 units of Pitocin were 41, 82 and 104 ml. of milk per udder, obtained during 80, 135 and 179 sec., respectively.

Except for a short period in summer, when a certain amount of skim-milk and cheese whey is available, dairy by-products are too scarce in Great Britain to be generally available for feeding to pigs, except possibly as a supplement to a meal mixture for suckling pigs. When the piglets are about 3 weeks old they begin to take solid food to augment the intake of nutrients provided by the sow's milk. It is important that the meal mixture given at this stage should be of good quality and as low in fibre as possible. An addition of 10 to 20 per cent. of dried skim-milk, dried buttermilk or dried whey to the cereal and protein supplement mixture will help to rear the litter successfully. Liquid skim-milk, provided it is fresh, can be given to suckling pigs instead of water as soon as they start eating solid food. It is usual to provide a small trough with skim-milk in the creep and let the piglets take it at will. The milk should be renewed at intervals as even slight souring will cause digestive disturbances. Whey should not be given to piglets before they are 6 to 8 weeks old, and then only in small quantities.

In the flush season, when dairy by-products are locally available in larger quantities, or in countries where there is abundance of them, it is essential that by-products should be fed either very fresh and sweet or completely sour. In the intermediate stages they might be harmful.

The question whether a supplement of acidified milk or milk by-products is more beneficial for pigs than one of sweet milk has not yet been satisfactorily answered. Recent extensive experiments in Denmark seem to support the claim that the growth rate and food utilisation can be improved by the inclusion of acidified milk in the ration. Trials at Shinfield have hitherto failed to substantiate this claim, but further tests are being carried out.

By-products which have become decomposed through being kept in dirty containers are not suitable for feeding to pigs. To prevent the spread of disease all dairy by-products, unless they are known to originate from healthy, tuberculosis-free herds, should be pasteurised before they are fed to pigs.

Experiments have shown that when skim-milk is fed in relatively small quantities it has an effect in excess of the total digestible nutrients contained in it, but further additions are beneficial only in proportion to the total digestible nutrients supplied by them. In these experiments when 2·5 to 5·0 lb. of skim-milk were fed per head daily, 4·1 lb. were found to be equivalent in nutritive value to 1·0 lb. of barley meal. When the amount fed daily was increased the barley replacement value also increased, and it took 10 lb. of skim-milk to replace 1·0 lb. of barley meal when the former was fed at a rate of 15 lb. per head daily.

Large scale experiments in America confirmed the view that in pig feeding restricted quantities of skim-milk have a higher nutritive value than that shown by analytical figures; thus, 9·9 lb. of dry matter contained in 100 lb. of skim-milk replaced 15·7 lb. of dry matter in maize supplemented by meat and bone meal. On the basis of these experiments the following scale for feeding skim-milk or buttermilk to obtain optimal results has been suggested:

Weight of pigs	*Lb. of skim-milk or buttermilk to 1 lb. of maize*
Just after weaning	4 to 6
50 to 100 lb.	2·5 to 3
100 to 150 lb.	2 to 2·5
150 to 200 lb.	1·5 to 2
over 200 lb.	1 to 1·5

Where barley or wheat is fed instead of maize, only one-half to two-thirds as much milk is used for each lb. of grain. Pigs fed on good pasture will need only about half as much milk for each lb. of grain.

Danish workers, after extensive experiments, have recommended very similar amounts of skim-milk as a supplement to cereals:

Weight of pigs	*Lb. of skim-milk per 1 lb. cereals*	*Lb. of skim-milk per pig daily*
55 to 100 lb.	2	6·2
100 to 145 lb.	1·5	6·2
over 145 lb.	1	6·2

Good results were obtained in Eire when 3 pints of skim-milk were fed per pig daily with a mixture of equal parts of cereals and potatoes.

On the other hand, experiments have shown that when large quantities of skim-milk are available there need be no hesitation in feeding fattening pigs with up to 2 to 3 gal. per head daily. In New Zealand, for example, pigs running on good pasture, after they reach the porker stage, may get nothing but skim-milk. However, it has been generally recognised, that to make the best use of it, the skim-milk must be supplemented by a mixture of cereals and protein concentrate.

Breeding stock should not be fed on dairy by-products alone. A high mortality has been observed in the litters of sows fed with plenty of skim-milk and little else.

The nutritive value of whey is one-half to two-thirds of that of skim-milk. As with the latter, better results are obtained with restricted than with unlimited quantities. Experiments in Australia have shown that pigs fed approximately 8 lb. of whey to each lb. of a mixture of cereals and meat meal developed to satisfactory bacon weight at the reasonable weight gain of 1·2 lb. per pig daily, while pigs fed approximately 14 lb. of whey to each lb. of cereals and meat meal mixture gained only at the rate of 1·0 lb. per day.

When large quantities of whey are fed it is important that the daily amount should be distributed over as many meals as possible. In New Zealand a routine is recommended in which whey is given to pigs five times during a day and the concentrates are added at the early morning and late evening feeds. Under the conditions prevailing there, where the pigs run on pasture, 3½ increasing to 6 gal. of whey is fed to fattening pigs, supplemented only by ½ increasing to 1 lb. of meat meal.

Dry sows and store pigs on good pasture can be maintained on whey alone. A dry sow can drink up to 18 gal. daily, but such quantities are not to be recommended. For optimal results whey should be supplemented with concentrates. If whey is fed *ad libitum*, weaners should get about 1 lb. of a balanced meal, baconers 2 to 3 lb. of ground cereals, and suckling sows at least 2 lb. of ground cereals plus ½ lb. of protein supplement daily. Pregnant gilts should not get more than 2 gal. per day.

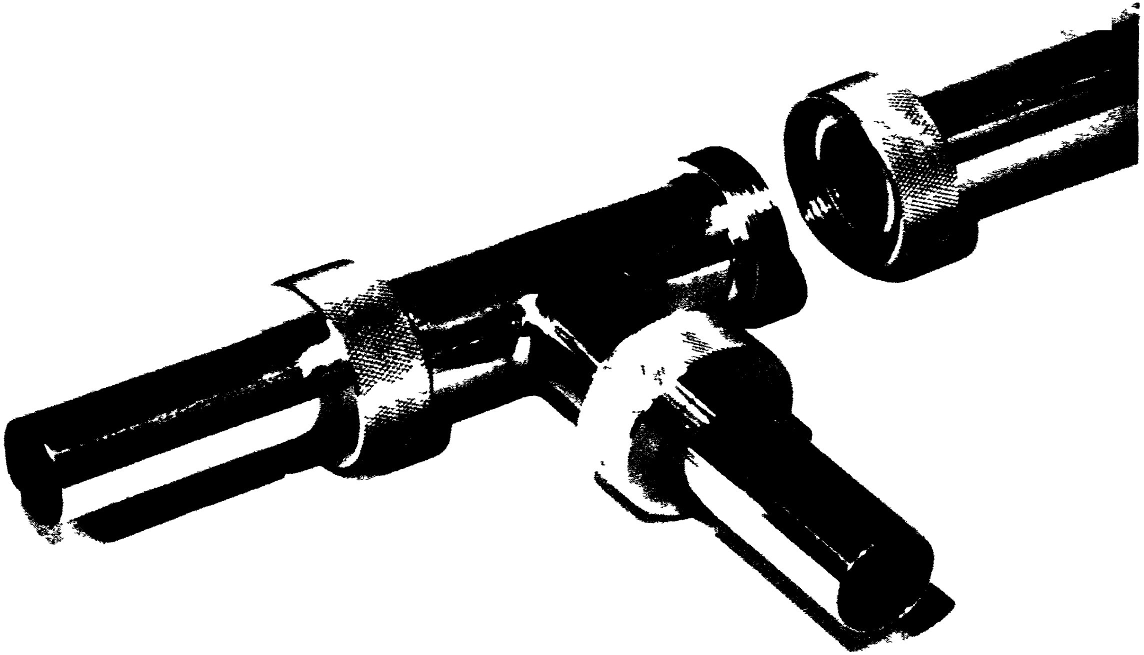
On the Continent pigs are often fattened on a diet of potatoes and whey. The potatoes are fed *ad libitum* and 1 to 1½ gal. of whey per head daily are added throughout the fattening period. In addition 1½ lb. of ground cereals and 3½ oz. of fish meal are also supplied whatever the weight and age of the animals.

The rationing of whey by feeding daily amounts of 10 per cent. of the animal's weight has been recommended.

Various methods of preserving surplus dairy by-products during the flush season to make them available for pig feeding at a later date have been used in the past. A detailed description was recently given of methods used in New Zealand for the preparation of curd which will keep satisfactorily for 6 to 8 months. Like silage, the curd is prepared from skim-milk or buttermilk by allowing acidity to develop and excluding air. The milk is soured and then agitated so that the curd is broken up to allow the gas to escape. The whey is drawn off, enough being left to cover the curd and exclude the air. This surplus whey can be fed to pigs. Curd made in this way contains about 10 per cent. dry matter of which 6 per cent. is protein. Most of the sugar is lost during fermentation. However, the feeding value is said to be about twice that of skim-milk.

Another method used extensively on the Continent for preserving surplus by-products is the preparation of whey paste. The fresh whey is concentrated up to 45 to 50 per cent. dry matter and an acidity of not more than 6 to 8 per cent. is allowed to develop. Whey paste can be fed several months after its production in quantities which will cover a large part of the food requirement of an adult pig.

In the production of lactose from whey, after the whey has been subjected to an evaporation process in vacuum and the sugar has crystallised and been removed, a residue is left called "mother liquor". It will keep well and has a



[By courtesy of T. Giusti and Son Ltd.

FIG. PL 1 — "Self fix" Pipelines

nutritive value similar to whey paste. It is not, however, very appetising, and digestive disturbances might result from feeding it to pigs unless it is broken down to 1 in 5 with water or whey. It then makes a useful food for pigs and up to 14 pints with 1 to 1¼ lb. of cereals daily have given satisfactory fattening results.

The drying of dairy by-products is an expensive process, usually too costly for general stock feeding purposes. Incidentally, since 2½ times more water has to be evaporated to produce 1 ton of dried whey than to produce 1 ton of dried milk, cost of drying for animal feeds is much higher than that for human consumption.

However, under some conditions, dried dairy by-products might be used in pig feeding. Supplementation of meal mixtures for suckling pigs has already been mentioned. In Denmark, for example, dried casein was found to be an excellent protein supplement, and able to compete on a cost basis with other sources of protein used in pig feeding. In America dried buttermilk gave very satisfactory results when fed as a protein supplement for pigs. It was proved better than meat and bone meal, but the best results were obtained when a mixture of these two protein-rich compounds was fed. Twelve lb. of buttermilk powder have a nutritive value equivalent to that of 100 lb. of skim-milk.

It is interesting to note that in experiments recently carried out in America liquid skim-milk fed to fattening pigs produced a daily gain of 1·75 lb. as compared with 1·34 and 1·45 lb. for drum dried and spray dried skim-milk supplying equal amounts of protein. When the dried skim-milk was reconstituted by the addition of water the pigs gained faster than when given the skim-milk dry, and they also utilised the feed with somewhat greater efficiency. *See* By-products ; Skim milk ; Whey.

Ref.: Whittlestone (1952), *JDR*, **19**, 127, 330, 335.

PIG MILK. *See* Mammals ; Pigs.

PIGMENTS. *See* Butter; Carotene; Cheese, pp. 182 and 192; Colour faults; Riboflavin: Stability; Vitamins; Xanthophyll.

PIN POINT COLONIES. This name is applied to very tiny colonies on the agar plate when making a plate count of milk. They are only just visible to the naked eye and hence are a nuisance in making plate counts. They were formerly more common before milk was incorporated into the medium. Pin point colonies may be due to two causes : (i) conditions preventing proper growth of the colonies, *e.g.* inadequate medium, overcrowded plates or inaccurate adjustment of *p*H; (ii) the presence of certain organisms, *e.g. L. thermophilus* and *Str. thermophilus*. *See* Plate count ; Thermophilic bacteria.

Refs.: Hammer ; Rogers.

PINT. A pint is defined as the eighth part of one gal. which is the volume of 10 lb. of water at 62 F. (*see* Weights and measures). It equals 0·56825 litre or 568·25 ml. It is the commonest measure of milk delivered in England and there is much to be said for standardising on the pint bottle, *i.e.* eliminating the ½ pint and quart sizes.

The English pint is divided into 20 fluid oz. The American pint is smaller (16 U.S. oz. or 0·83 British pints). *See* Bottle filling; Legal aspects.

PIPE LINES. Milk is normally transferred from one tank to another, or to pasteurisers, coolers, etc., by being pumped through pipe lines. There is now a tendency to use stainless steel pipe lines but junctions are frequently made of tinned bronze.

A new type of " self-fix " pipe-line is illustrated in Fig. PL 1.

Pipe lines are one of the worst sources of contamination of milk ; they should be rinsed through immediately after use and cleaned with hot detergent and sterilised by steam, hot water, or chlorine immediately before use (*see* Cleaning and sterilising of plant).

Glass pipe-lines are now being used with increasing frequency. They have the advantages of transparency, hardness, ease of cleaning, non-corrodibility, and cheapness. Glass pipe-lines can be cleaned *in situ* by flushing, treatment with hexametaphosphate followed by detergent, and rinsing. They may be sterilised by hot water or chlorine solution.

Pipe lines should be kept to a minimum and there should always be a good fall. A sagging or “ hollow ” in a pipe line should be avoided at all costs. *See* Management of creameries ; Pumps.

Refs.: Ormiston *et al.* (1953), *JDS*, **36**, 596; Window (1953), *D*, **70**, 421 ; Sheuring and Henderson (1952), *JMFT*, **15**, 186; Alexander *et al.* (1952), *JDS*, **35**, 874; (1953), **36**, 303; B.S. 1864 (1952); Moore *et al.* (1951), *JDS*, **34**, 804; Fleischman (1952), *MD*, **41**, April, 130 (permanent).

“ PITTING.” The development of little cavities in metal plant, especially in aluminium. They are caused by the development of lactic acid by bacteria in milk residues. Pitting can also be caused by corrosion by brine, etc. *See* Brine ; Corrosion; Metals.

PITUITARY GLAND OR BODY ; PITUITRIN. *See* Glands ; Hormones ; Milk secretion.

PLANT, DAIRY. This term is used loosely for all engineering equipment, especially that for pasteurising, cooling, bottle washing, filling and capping, steam raising, refrigeration, etc. *See* Bottle filling and capping; Bottle washing; Cleaning and sterilising; Cooling; Design of dairies; Detergents; Electrical equipment; Management of creameries, of dairies; Pasteurisation; Refrigeration; Steam raising.

Refs.: Cronshaw ; Cuttell ; Enock ; Farrall ; Harvey and Hill ; Hill ; Mortensen (1938), *Management of Dairy Plants*, New York.

PLASTICS. Plastic bottles are not suitable for milk, on account of cost and cleaning and sterilising problems. *See* Packaging.

Refs.: Smith (1951), *DI*, **16**, 253 ; Yarsley (1946), *Plastics Applied*, London.

PLATE COUNT OF MILK. There is no method of bacteriological analysis that is accurate in the sense that a chemical determination is accurate. Consequently, there are in common use a variety of methods for estimating the bacterial content of milk and its products, each having its characteristic advantages and disadvantages.

The Plate Count. This is generally accepted as the most accurate method of estimating the bacterial content of milk and was formerly the official test for all designated milks. The method consists in mixing various dilutions of the milk with a nutrient agar medium, pouring into plates, incubating for 2 days at 37° C and counting the colonies that grow under these conditions.

Medium.

Yeastrel	3 g.
Peptone	5 g.
Agar	15 g.
Fresh whole milk	10 ml.
Distilled water	1000 ml.

Dissolve the yeastrel and the peptone in distilled water in the steamer and adjust the reaction at room temperature to *p*H 7·4, using phenol red as the indicator. Wrap the shredded agar in muslin and wash in running cold water for 15 min. Squeeze out the excess cold water and add the agar together with the freshly shaken milk to the broth. Autoclave at a pressure of 15 lb. per sq. in. for 20 min. and filter through paper pulp in a Buchner funnel. Egg must not be used for clearing. The pulp is prepared by mashing up small pieces of “ postlip ” or “ white heather ” paper in water by means of a pestle and mortar. A single layer of Chardin filter-paper should be laid on top of the Buchner funnel to prevent the pulp being sucked through, and the pulp itself should then

TABLE PT I

(Relation Between 10 Min. Resazurin, Keeping Quality and Other Tests)

Disc no. 10 min. resazurin	*Comments*	*No. of samples*	*K.Q. time C.O.B. at 18° C. in hr.*			*Plate count at 37° C. in millions*			*Bacterial clump count*			*Methylene blue at 37° C. in hr.*			*Resazurin disc no. at 1 hr.*		
			Mean	*Lowest*	*Highest*	*Mean*	*Lowest*	*Highest*	*Mean*	*Lowest*	*Highest*	*Mean*	*Lowest*	*Highest*	*Mean*	*Lowest*	*Highest*
6	Indefinite grade Fair or good milk	7	19·1	8·5	26·5	3·73	0·1	9	2·36	<0·1	12	2·86	1·0	5·0	3·64	0	5·5
5½ to 5	Satisfactory for acceptance	8	18·8	8·5	27	73·6	12	400	5·5	1·3	18	1·5	0·5	2·5	1·2	0	4
4½ to 4		15	11·3	0·3	16	262·1	3·5	800	16·2	0·4	60	0·8	0·5	1·0	0·14	0	2
3½ to 3	Unsatisfactory should be rejected	21	10·6	3·5	16	523	15	600	18·7	0·3	54	0·74	0·17	1·5	0·1	0	2
2½ to 2		12	8·2	6·0	13·5	391·3	18·4	1000	22·4	1·6	45	0·8	0·17	1·0	0	0	0
½ to 0	Really bad milk, should invariably be rejected	14	5·3	1·0	10	501	16	1500	24·7	2·4	60	0·22	0·17	0·5	0	0	0

be packed down evenly on top of it. The funnel should be inserted into an Erlenmeyer filtration flask fitted with a side-piece. A filter-pump should be applied to suck through the excess water, which should be poured off through the side-piece. The filter, when ready for use, should have a total depth of about 1·5 mm. A pulp layer of suitable and approximately the same depth for any size of funnel may be obtained by pulping an area of dry postlip filter-paper equal to four times the square of the diameter of the funnel. The agar is taken directly from the autoclave and filtered hot, the whole apparatus being kept warm by a surrounding atmosphere of steam. The reaction of the filtrate is tested at 50° C. and adjusted, if necessary, to *p*H 7·0. The medium is tubed in 10 ml. quantities and autoclaved at a pressure of 15 lb. per sq. in. for 20 min. The final reaction of the medium at room temperature should be *p*H 7·2.

Not more than 15 min. should elapse between the preparation of the dilutions and the pouring of the plates. After incubation, plates showing not less than 30 or more than 500 colonies are counted, using a specially constructed box and a magnifying glass of 4 in. focal length magnifying 2½ times. *See* Bacteriological equivalents; Bacteriological grading; Media; Methylene blue test.

Refs.: Milk Testing; Wilson *et al.*; Chalmers; Barkworth *et al.* (1941), *JDR*, **12**, 265; Min. Health (1937), Memo. "139/Foods", H.M.S.O.; Min. Agric. (1932), "Guide to the Conduct of Clean Milk Competitions", Bull. 46, H.M.S.O.

PLATING (METALS). *See* Metals.

Ref.: Sanderson (1951), *DI*, **16**, 148.

PLATFORM TESTING OF MILK. The whole quality of the milk supply depends on the efficiency of platform testing at receiving depots. Unfortunately, the peak intake often coincides with hot weather and the rush on the platform sometimes results in slips in platform testing or impatience on the part of the checker. In the absence of any mechanical device or scientific apparatus for the rapid detection of faulty milk, all depots depend on the ability of the checker or platform examiner to weed out any faulty milk. There is no universally acceptable definition of *unmarketable milk* but since 1942 a standard of disc 3½ or less in the 10 min. resazurin test (equivalent to ½ hr. or less in the methylene blue test) has been accepted by most buyers in this country as a *rejection standard.* The universal practice therefore is for the churn of farmer's milk to be opened and smelled by the checker. If any suspicious taint is present, the churn is put on one side for a laboratory test—usually the rapid resazurin test. The keeping qualities

TABLE PT II

ACCURACY AND SPEED IN BACTERIOLOGICAL TESTS

Test	*Time required*	*Accuracy* (*in relation to keeping quality*)[2]
Smell	3 sec.	+
*p*H (glass electrode)	15 sec.	+ +
Alizarin-alcohol [1]	15 sec.	+ +
Titratable acidity	1 min.	+ +
Clot on boiling [1]	1 min.	+ +
Rapid resazurin	10 min	+ + +
Routine resazurin	15 to 120 min.	+ + + +
Methylene blue	2 to 8 hr.	+ + + + +
Dye tests at 18° C.	6 to 24 hr.	+ + + + + +
Plate count at 37° C.	2 days	+ + + +
Coli at 37° C.	2 days	+ + + +
Keeping quality	2 to 3 days	+ + + + + + +

[1] Only one "end-point" with this test.

[2] With reference to rejection at ½ hr. methylene blue standard.

and other bacteriological properties of milks of various disc numbers in the 10 min. resazurin test are illustrated in Table PT I. No quick test can be as accurate as the longer tests as shown in Table PT II. *See* Bacteriological grading; National Milk Testing Scheme; Resazurin tests; Routine tests; Testing of milk supplies.

Refs.: Chalmers; Hammer; Wilson *et al.*; *Milk Testing;* Griffiths *et al.* (1953), *JSDT*, **6**, 37; Clegg (1952), *DSA*, **14**, 731; Campion *et al.* (1950), *SAB*, **13**, 116; Cuthbert (1948), *SAB*, p. 3; Jones-Evans (1949), *JSDT*, **2**, 232; Hughes and Ellison (1949), *JSDT*, **2**, 149; Higginbottom (1948), *DI*, **13**, 1187; Davis *et al.* (1943), *DI*, **8**, 23, 71 and 115; Barkworth *et al.* (1943), *DI*, **8**, 215; Thomas and Phillips (1942), *SAB*, p. 22; Davis (1939), *DI*, **4**, 221.

PLEOMORPHIC. Having more than one form. Certain types of bacteria are pleomorphic, especially the higher types, and this sometimes leads to difficulty in their identification.

POINTS OF THE DAIRY COW. *See* Breeding.

POISEUILLE'S LAW. If a liquid flows through a capillary tube, for laminar flow conditions the rate of flow is given by the formula

$$\frac{V}{t} = \frac{\pi r^4 \Delta p}{8\eta l}$$

where V = volume in time t; r = radius; Δp = pressure difference at ends of tube; l = length of tube; η = viscosity of liquid. *See* Flow of liquids; Rheology; Viscosity.

POISONING. *See* Food poisoning.

POLAND.

Ref.: Majewski (1936), *Technical and Social Changes in Dairying in Western Europe and Poland* (in Polish), Krakow.

POLARIMETER. An instrument for measuring the optical rotation (p. 775) or activity of solutions. It consists of two Nicol's prisms, one of which can be rotated, and which have the power of *polarising* or " filtering out " light waves in one plane. If the prisms are set at right angles no light will get through the long axis on which the prisms are set. If, however, a tube containing a solution of an optically active compound is placed between the prisms, the plane of the polarised light waves is rotated so that light gets through the second prism. If the second prism is now rotated a point is found at which the light is once again cut off. This angle is a measure of the optical activity of the solution, or, if the specific rotation of the solute is known, of the concentration of that solute. Sugars and many organic compounds are optically active and so can be estimated by polarimetric measurement. The specific rotating power is given by the formula:

$$[\alpha]_D^{20} = \frac{100\,a}{l\,.\,c}$$

where a = observed rotation; l = length of tube of solution *in decimeters*; c = concentration in g. per 100 ml.

Values of $[\alpha]_D^{20}$ for sugars are: maltose + 139·5°, sucrose (cane sugar) +66·5°, lactose (milk sugar) + 55·3°, dextrose (glucose) + 52·7°, lactose monohydrate + 52·5°, invert sugar − 20° and fructose (laevulose) − 93·8°. *See* Optical activity.

Ref.: Richmond.

POLENSKE METHOD. This analytical test for fat is a measure of the insoluble volatile fatty acids (p. 462) and includes only caprylic and higher acids. The Reichert method (p. 901) detects only up to capric acid, lauric and the higher acids being, under the conditions of the test, completely insoluble. The ratio of the Reichert to the Polenske value for a fat really defines the proportion of the lower volatile fatty acids (chiefly butyric and caproic) to the higher (chiefly capric and lauric) and their relationship for butter is given by the formula:

$$0{\cdot}033\ R - 0{\cdot}6155 = \log_{10}(P - 0{\cdot}48)$$

and is illustrated in the following table:

Reichert figure	*Polenske figure*		
	Calculated	*Mean*	*Maximum*
30	2·85	2·8	3·3
25	2·14	2·1	2·6
21	1·70	1·7	2·2

It is essential that a standardised method be used (*Soc. Publ. Anal. A* (1936), **61,** 404).

POLICY. *See* Legal aspects; Milk marketing; Milk (Special Designations) Order; National Milk Testing Scheme; Pasteurisation; Quality payment.

POLLUTION. *See* Effluent.

POMMEL. *See* Cheese, p. 198.

PONT L'EVÊQUE. *See* Cheese, p. 198.

PORPOISE MILK. *See* Mammals.

PORT DU SALUT. *See* Cheese, p. 198.

POTASSIUM. One of the alkali metals which is present in relatively large quantities in milk.

POTATO CHEESE. *See* Cheese, p. 199.

POUND. The standard British unit of weight, equal to 7000 grains, 1/2240 ton and 453·59 g. It is the weight of 27·692 cu. in. of water at 4° C.

POWDER. *See* Milk powder.

POWER. Power is the rate of doing work. The scientific unit is the watt or 10^7 erg. per sec. 1 H.P. = 746 watts.

PRECONDENSING. *See* Condensed and evaporated milk; Milk powder.

PREGNANCY DIAGNOSIS. An early diagnosis of pregnancy in the cow is of prime importance to the dairy farmer in carrying out breeding programmes and controlling infertility. At present the only reliable method of pregnancy diagnosis in the cow is the clinical examination of the animal by a veterinary surgeon. This examination involves the palpation, through the wall of the rectum, of the reproductive organs, in particular the uterus. A diagnosis can usually be made somewhat earlier in heifers than in cows, but in the majority of animals a definite opinion can be given six to eight weeks after service. The risk of injury to the animal by such an examination is now known to be negligible; it is, however, a skilled procedure, and should only be carried out by a veterinarian. In animals found not to be in calf, such an examination has the added advantage that it may reveal abnormal conditions in the reproductive organs which may indicate the cause of the sterility.

In the woman and in the mare there are certain laboratory tests which can be made on the blood and urine which will give a very accurate indication as to whether or not the patient in question is pregnant. These tests in general depend on the detection of certain hormones which occur in large quantities in the blood and urine of women and mares during pregnancy. These tests are well known by such names as the Aschheim-Zondek test, the Friedman test, the Xenopus test, the Toad test and the Frog test. These tests are of *no value in the cow or heifer* because the hormones in question do not occur in appreciably increasing amount in the blood or urine during pregnancy,

For further information on pregnancy tests see reviews by Cowie in *Vet. Record* (1951), **63,** 371, and "Pregnancy Diagnosis Tests—A Review" (1948), *Commonwealth Agricultural Bureaux Joint Publication* No. 13. *See* Breeding; Milk secretion; Oestroscope.

PRESERVATION OF MILK SAMPLES. For bacteriological purposes, refrigeration is the only method permissible and even then it is best avoided. The best temperature for this purpose is 35° to 40° F.; at 43° F. and higher bacteria begin to grow and below 35° F. they slowly die off. Broadly speaking, refrigeration improves low-count milks and allows high-count milks to deteriorate somewhat.

For chemical purposes a number of preservatives can be used and the choice depends on the purpose of the analysis. These are summarised below.

Preservative	*Amount*	*Remarks*
Alcohol	Twice volume of milk	Volatile substance added. Salts and lactose deposit.
Chloroform	1 per cent.	Enzymes not completely stopped. Good for short periods.
Ether	7 per cent.	As for chloroform.
Formalin	0·1 per cent.	Very useful. Raises fat and solids-not-fat values slightly.
Hydrofluoric acid	½ per cent.	Milk curdled. Glass goes into solution.
Mercuric chloride (corrosive sublimate)		Suitable for fat.
Potassium bichromate		Suitable for fat.
Sterilisation (autoclaving)		Slight changes in sugar and protein.

Ref.: Richmond.

PRESERVATIVES. The use of preservatives for milk has been illegal since the Food and Drugs Act, 1926, 1938, but formerly it was common and many chemicals were used, chiefly formalin, boric acid, hydrogen peroxide, and hypochlorites. These are now only of scientific interest except hypochlorites and formalin. The former is now permitted for the chemical sterilisation of utensils on the farm, so that it is not surprising if occasionally some chlorine gets into the milk by accident. Formalin is still found on rare occasions.

Ref.: Richmond.

PRESSURE. Pressure is defined as the compressive force per unit area. The mean pressure of the atmosphere at sea level is 14·6974 lb. per sq. in. *See* Autoclave.

PRESUMPTIVE STANDARDS (CHEMICAL). The presumptive standards for milk are 3 per cent. fat and 8·5 per cent. solids-not-fat. Milk which is below either of these limits is presumed adulterated (*i.e.* to contain added water) until the contrary is shown. *See* Appeal to the cow test; Freezing point test; Legal aspects; Standards, chemical.

Ref.: Richmond.

PRESUMPTIVE TESTS (BACTERIOLOGICAL). *See* Coliforms.

Ref.: Wilson *et al.*

PRICE TO THE CONSUMER, METHODS OF REDUCING. The biggest proportions of the cost of milk are due to the cost of production and the cost of distribution, the cost of bulk transport and processing being relatively small. The most fruitful field to explore for reducing the cost to the consumer is therefore in distribution. This can only be done by reducing the number of deliveries, or by selling milk in powder form through the grocer. Laboratory-pasteurised milk has extraordinarily long keeping qualities at refrigerator temperatures and it is not uncommon for such milk to remain sweet for a month. One solution, therefore, when domestic refrigerators become universal, would be a once-weekly delivery of "in-bottle" or very efficiently pasteurised and bottled milk. It might be said that quality payment, efficient heat-treatment of all milk except high-grade T.T. milk, and universal domestic refrigeration are the three most

TABLE Pri I

AVERAGE PRICES RECEIVED BY THE PRODUCER FOR WHOLE MILK (NATIONAL CURRENCIES)

Country	1938	1947	1948	1949	1950	1951
United Kingdom (pence per gal.)[1]	12·95	26·25	28·59	29·64	31·54	32·80
Canada (cents per lb.)	1·35	2·37	2·94	2·66	2·58	2·87[10]
Australia (Australian pence per lb. commercial butter)[2]		24·0	26·0	28·5	30·27[11]	42·02
New Zealand (N.Z. pence per lb. of butterfat used for butter manufacture)[3]	15·88	25·91	26·75	28·24	29·68	33·66
U.S.A. (cents per lb.)	1·72	4·26	4·87	3·94	3·88	4·87[5]
Denmark (ore per kg.)	17·34	30·43	36·27	37·32	34·58	34·34[5]
Netherlands (cents per kg.)[4]	11·00[7]	18·30	17·50	18·00	17·50	20·00
France (Fr. per litre)				20·86[9]	21·75	29·00[12]
Switzerland (centimes per litre)[6]		38	38	38	38	37

[1] Twelve months ending 30 Sept. of year stated. (Pool price for England and Wales).

[2] Twelve months ending 30 June following year. (Guaranteed price.)

[3] Twelve months ending 31 July following year. (Basic price at beginning of season.)

[4] Twelve months ending 5 Nov. following year. (Fixed price for milk of 3·3 % fat content up to 1948 and for milk of 3·5 % fat content thereafter.)

[5] Estimated.

[6] Twelve months ending 30 April following year.

[7] 1941.

[9] Twelve months ending 30 Sept. following year.

[10] January-August.

[11] Raised to 32·44d. from 1 Dec. 1950.

[12] Average winter price 1 Oct. 1951-31 Mar. 1952: corresponding price for previous winter was 25 Fr. per litre.

TABLE Pri II

AVERAGE PRICES PAID FOR MILK IN ENGLAND AND WALES (OCTOBER-SEPTEMBER)

(pence per gal.)

Description	1937-38	1938-39	1946-47	1947-48	1948-49	1949-50	1950-51 [3]
Liquid milk	16·26	16·25	26·25	29·17	28·8	28·89	29·70 [4]
Manufacturing milk:							
Butter	5·31	5·56	12·23	12·58	11·83	11·76	11·76
Cheddar cheese	6·45	5·42	8·00	8·00	8·00	8·00	8·00
Condensed milk [1]	7·50	7·50	19·00	19·00	19·57	20·11	19·00
Milk powder	7 00	7·00	19·00	19·00	19·00	22·90	24·00
Fresh cream	8·50	8·50	—	—	—	—	—
Tinned cream	7·37	7·50	—	—	—	—	—
Ice cream	8·50	8·50	—	—	—	24·00	—
Other products	10 00	10·00	22·25	22·25	23·02	23·88	28·00
Average manufacturing price . . .	6·8	6·60	14·39	15·16	13·25	13·80	13·25
Pool price received by farmers [2] . .	12·92	12·95	26·25	28·59	29·64	31·52	32·80
Average cost of transport . . .	1·44	1·43	1·03	0·93	0·93	0·93	0·95
Net return to farmers [2]	11·48	11·52	25·22	27·66	28·71	30·61	31·85

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[1] Milk manufactured into *condensed milk for export* in the two pre-war years was the same as for Cheddar cheese subject to a minimum of 5d per gal. in 1937-38 and 6d. per gal. in 1938-39; in 1949-50 a special price of 24d. per gal. was charged for milk manufactured into condensed milk for export.

[2] Excludes production bonus payable since January 1944 at following rates: ½d. per gal. on first 500 gal. sold in each summer month (April-Sept. until 1951 when milk produced in Sept. qualified for winter rate) and 1½d. per gal. (3d. in 1950-51 and 3½d. in 1951-52) on the first 400 gal. sold in each winter month. Also excludes quality premiums.

[3] Provisional.

[4] Actual prices were Oct.-Dec. 1950—29d., Jan.-Jun. 1951—28·75d., July-Aug. 1951—32·5d., Sept. 1951—32·17d.

urgently wanted reforms in the milk industry. *See* Costings; Milk marketing; Quality payment; Retail dairying.

Ref.: Williams.

PRICES OF MILK. The present retail prices in England (Feb. 1954) are (per pint):

Ordinary pasteurised . .	6½d.
Homogenised	6¾d.
T.T. pasteurised . . .	7d.
Sterilised	7d.
Channel Islands and South Devon	7½d.
Certified	8d.
Kosher	7d.
Kedassia	9d.

Other types, *e.g.* separated, T.T. (Farm-bottled), etc., are a matter of agreement.

The average prices received by producers in various countries are given in Table Pri I, and the prices paid by users in England and Wales are given in Table Pri II. The prices of dairy products and other foods in some European countries are given in Table Pri III.

TABLE

RETAIL PRICES OF FOOD IN THE UNITED KINGDOM AND

Shillings and

Commodity	*United Kingdom*		*France*		*Switzerland*		*Italy*	
	1951 Oct.	1952 Oct.	1951 Oct.	1952 Oct.	1951 Oct.	1952 Oct.	1951 Oct.	1952 Oct.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d	s. d.	s. d.
Bread	4	4½	5½	5½	4½	4½	6	6¼
Potatoes	1¾	2	1¾	2¾	3	3	2	2¾
Sugar	6	7	1 0½	1 2	10¼	9¼	1 4¼	1 4¼
Butter	2 6	3 0	6 7½	7 4¾	7 4½	7 4½	6 1	6 0¾
Margarine . . .	1 2	1 4	3 1¾	3 0¾	n. a.	n. a.	n. a.	n. a.
Lard or cooking fat .	1 4	1 6	3 9½	3 4	2 6½	2 3½	n. a.	n. a.
Cheese . . .	1 2	2 2	5 1½	5 10½	3 11	4 1¼	5 0½	4 9¼
Eggs per dozen) . .	5 0	5 0	5 9	5 9	6 9	6 6	5 3	3 9
Beef (rib roast) . .	2 0	2 4	2 8¾	2 7½	4 7¾	4 8¼	4 9½	4 11¼
Mutton (leg) . .	2 4	2 10	6 6½	7 2½	5 4½	5 6¾	n. a.	n. a.
Pork (chops) . .	2 10	3 4	4 5¾	4 10½	6 1¾	6 2¼	4 8	4 8
Bacon (including gammon) . . .	2 7	4 0¾	3 7½	3 0¼	5 11¾	5 11½	3 2½	2 8
Tea	(*a*) 3 8	(*a*) 4 6	n. a.	n. a.	11 11	12 0¼	n. a.	n. a.
Coffee . . .	(*a*) 4 10	(*a*) 6 0	8 7	8 6	6 2½	6 8½	9 4	9 4¾

(*a*) Estimated.

PRIMOST. *See* Cheese, p. 199.

PROBABILITY. (i) The probability of an event occurring can be expressed as a simple percentage or ratio on the basis of a large number of observations. Thus the probability of a genuine milk having a freezing-point depression of less than 0·541° C. may be 255 in 1000 or 25·5 per cent. but only 10 in 1000 or 1 per cent. may have a depression of less than 0·533° C. (Stubbs and Elsdon, *A* (1934), **59**, 146).

(ii) Probability is an important factor in the modern theory of statistics and in assessing the validity of a difference between results from control and experimental groups, *e.g.* of animals, the probability of the result being due to chance is calculated. Various factors will affect this value, *e.g.* the number of units in the groups, the accuracy of the experimental methods, etc. If it is found for example, that the probability of the result (or difference between groups) being due to chance is only 1 in 20 (P = 0·05) it may be assumed that the difference is a real one and that the factor studied, *e.g.* a dietary factor, had a significant effect upon the experimental group. *See* Statistical formulae.

PROCESSED CHEESE. *See* Cheese, p. 199.

PROCESSING. This term is used in a wide sense in dairying and includes pasteurising and bottling, condensing, evaporating, drying, etc. It is always preferable to use a specific term rather than a general one when only one process is meant. *See* Management of creameries, of pasteurising depots.

PRODUCER-RETAILER. A producer-retailer is a milk producer (dairy farmer) who sells his own milk to his customers. The increases in urban population, big dairy companies and in pasteurisation have all tended to reduce the number of producer-retailers in this country, there being about 40,000 at the present time.

Pri III

CERTAIN OTHER O.E.E.C. COUNTRIES

Pence per lb.

Netherlands		*Austria*		*West Germany*		*Denmark*		*Norway*		*Sweden*	
1951 Oct.	1952 Oct.	1951 Oct.	1952 Oct.	1951 Oct.	1952 Oct.	1951 Oct.	1952 Oct.	1951 Oct.	1952 Oct.	1951 Oct.	1952 Oct.
s. d.	s. d.	s. d.	s. d.	s d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
3¾	4½	5½	5¼	5¾	5¾	6¼	6½	6¼	6	10½	11½
1½	1½	1¼	2	1½	2	2	2	2	2¾	2½	3
9¼	9¼	10	10	1 0¼	1 0¼	4	4	4½	4½	9	10½
3 9	3 9½	4 3	4 3	4 10½	5 2¾	2 11	3 4	3 7¼	3 7½	4 0¼	4 2¼
1 9¼	1 6	1 3½	1 3½	1 8	1 3½	1 10½	1 7½	1 1	1 2	2 3	2 5
2 2¼	2 1¼	2 0	2 0	n. a.	n. a.	2 2¾	1 3¾	1 2½	1 3	n. a.	1 11¾
2 5¼	2 4¼	3 2¼	3 2¼	n. a.	n. a.	2 5½	2 7¾	1 9¼	2 2½	2 1½	2 7½
5 0	4 6	4 6	4 3	5 6	5 3	4 3	4 6	n. a.	n. a.	2 9¾	2 6¼
3 3¼	3 5	2 6	2 8¾	3 1	3 3½	2 7½	2 9½	3 0¼	4 5½	n. a.	2 6¾
n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	3 1	3 6	3 8¾	4 4
3 8	3 9½	2 6	3 7¼	3 10¼	3 10	2 9½	3 3	3 4½	3 9¼	3 10½	4 7
2 10¾	2 11	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	3 5¾	3 9½	n. a.	5 6¼
7 10¼	n. a.	14 11½	14 11½	n. a.	n. a.	10 0½	10 0½	13 0	13 3¼	n. a.	n. a.
6 6½	n. a.	7 5¾	11 10	25 1¼	24 10½	6 11¾	3 10½	3 10½	3 10½	7 3¼	7 8

n. a. = Not available.

Producer-retailers thrive best in rural areas and on the outskirts of provincial towns. They have the advantage of delivering their milk fresh to the consumer but their scale of working often does not justify heavy capital expenditure on plant. Producer-retailers nearly always sell raw milk but their herds are very largely tuberculin-tested or attested. Even if the raw milk is free from the tubercle organism, it is always liable to infection from human sources (see Diseases). Raw milk is therefore always a greater risk than pasteurised milk and it is likely

PRODUCER-RETAILER

TABLE Pr I

PRODUCER-RETAILERS CHANGES DURING THE PAST TEN YEARS

Region	*The number of producer retailers*		*Retail sales of own production—million gals.*		*Percentage decrease in ten years*	
	1941	1951	1941-2	1950-1	*Numbers*	*Sales*
1. Northern	6,810	4579	17·15	15·46	33	10
2. North Western	15,488	9906	62·37	59·16	36	5
3. Eastern	5,122	2285	14·05	10·67	55	24
4. East Midland	4,451	2222	13·86	10·12	50	27
5. West Midland	5,223	3045	13·33	9·76	42	27
6. North Wales	3,455	2306	6·04	5·57	33	8
7. South Wales	4,025	2606	7·43	6·45	35	13
8. Southern	3,423	1497	12·27	8·58	56	30
9. Mid-Western	4,769	2426	11·39	8·04	49	29
10. Far Western	6,221	4041	10·65	9·44	35	11
11. South Eastern	3,769	1553	20·29	14·65	59	28
Total	62,756	36,466	188·83	157·90	42	16

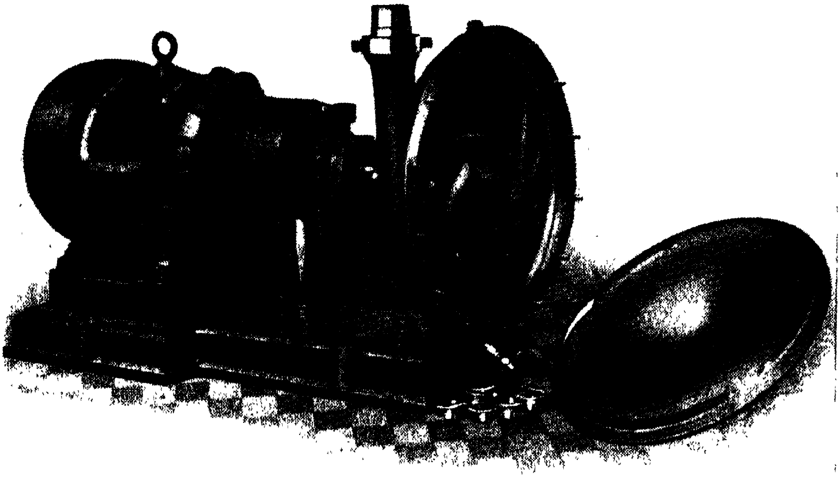
NUMBER OF RETAILERS

	With Wholesale Contracts	*Without Wholesale Contracts*
March 1941 (Approx.)	31,500 (50 %)	31,250 (50 %)
March 1951 (Approx.)	26,739 (73 %)	9,727 (27 %)

TABLE Pr II

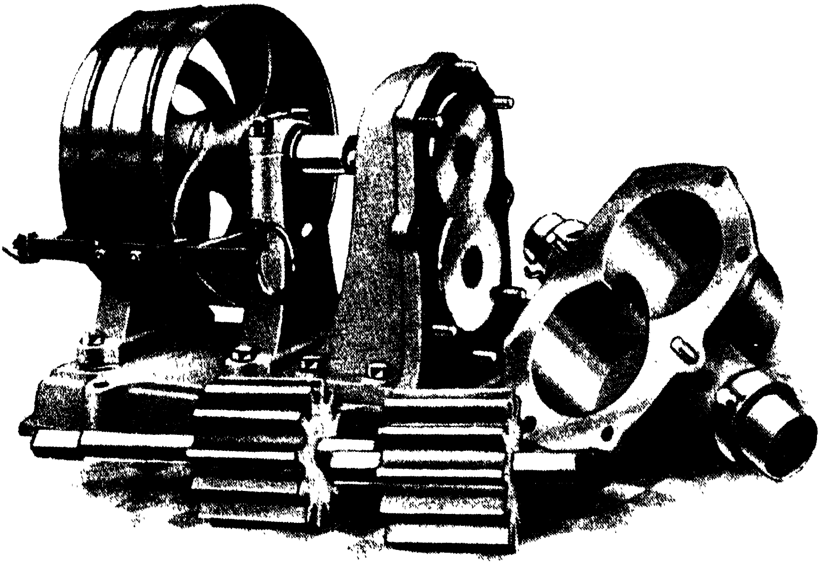
THE SIZE OF PRODUCER-RETAILERS' BUSINESSES

Daily retail sales of own production (gal.)	*April* 1941	*April* 1951
	% *of total*	
Less than 1	31·6	21·3
1 but less than 2	13·9	16·0
2 but less than 3	7·8	9·6
3 but less than 4	5·4	6·2
4 but less than 5	4·3	4·4
5 but less than 10	13·0	12·4
Less than 10	76·0	69·9
10 but less than 15	7·9	7·2
15 but less than 20	4·9	5·2
20 but less than 30	5·4	7·0
30 but less than 40	2·5	4·0
40 but less than 50	1·3	2·4
50 but less than 60	0·7	1·3
60 but less than 100	0·9	2·0
100 and over	0·4	1·0
Total	100·0	100·0



[By courtesy of Robert Morton Ltd.

FIG. Pu 1.—*Stainless Steel Pump with Toggle Bolts, Cover, and Impeller Removed.*



[By courtesy of Robert Morton Ltd.

FIG. Pu 2.—*Rotary Pump Taken Apart for Cleaning.*

TABLE Pr III

THE PRODUCTION OF PRODUCER-RETAILERS' SALES EARNING T.T. OR ATTESTED PREMIUMS

	%		%
1. Northern . .	49·9	7. South Wales . .	48·8
2. North Western .	33·2	8. Southern . .	56·1
3. Eastern . .	47·0	9. Mid-Western .	51·0
4. East Midland .	30·6	10. Far Western . .	32·4
5. West Midland .	43·9	11. South Eastern .	64·9
6. North Wales .	52·9		
		All regions .	42·6

that the producer-retailer will become numerically less and less important. Nevertheless, producer-retailers sell some of the best milk in the country both from the chemical (fat and solids-not-fat) and bacteriological (keeping quality) point of view.

General Data. The number of producer-retailers has been falling almost continuously since 1936. *See* Tables Pr I, II and III.

See Costings; Milk marketing; Retail dairying.

PRODUCTION OF MILK IN ENGLAND AND WALES. According to the Ministry of Agriculture's records, there are about 2,800,000 cows in England and Wales. Not all of these cows are in herds from which milk is sold; the Milk Marketing Board's records indicate that some 10 to 15 per cent. of the cows recorded by the Ministry of Agriculture are kept for beef production, stock rearing and so on.

At the present time, milk is sold off the farm by about 157,000 milk producers. The number of producers selling milk has grown considerably since the introduction of the Milk Marketing Scheme, especially in the areas distant from the large urban consuming centres.

Wartime conditions have accelerated this tendency for farmers in the outlying areas to sell their milk off the farm rather than manufacture it into butter and cheese on the farm, or use it for calf rearing.

Production Trend. Before the war, dairy farmers depended almost exclusively on purchased concentrates for the production ration. Wartime conditions brought about a complete reversal of farming practice; it was then essential to make the dairy farm self-sufficient. In the established dairying areas this revolution in dairy farming brought about a serious fall in yields; and until 1941, when the Ministry of Agriculture initiated their milk production campaign, the total quantity of milk sold off farms declined.

THE NUMBER OF WHOLESALE SUPPLIES

Region	1934	1939	1946
Northern	6538	10318	14815
North Western . . .	19421	23863	26845
Eastern	3743	6176	7832
East Midland . . .	6685	7535	8208
West Midland . . .	7058	9401	11490
North Wales . . .	1712	4132	8178
South Wales . . .	4502	9804	13302
Southern	5357	6140	6754
Mid Western . . .	11168	12302	13149
Far Western . . .	6219	11583	16655
South Eastern . . .	6492	6764	7522
All regions . . .	78985	108018	134750

From that date, supplies increased continuously; and in the 12 months ended September, 1946, over 200 million gal. more milk were sold off farms than in the bottom year 1940-41 :

TOTAL SALES OF MILK OFF FARMS

October-September	*Million gal.*
1938-39	1119
1939-40	1071
1940-41	1045
1941-42	1079
1942-43	1145
1943-44	1180
1944-45	1204
1945-46	1259

Before the war only about 5 per cent. of the total concentrates fed to dairy cows were home grown; the proportion is now about 40 per cent.

Greater attention has been given to the economical use of labour ; many more dairy farms, for instance, are using milking machines, and there are now about 90,000 in use.

Small Herds. On the whole, dairy herds are small ; indeed, the Board estimates that the average size of herd is only 15 cows :

DISTRIBUTION OF MILK SELLING HERDS ACCORDING TO SIZE OF HERD

No. of cows per herd	*No. of herds*	*% of total herds*	*% of total cows*
Less than 5	23800	15·1	3·1
5 to 9	43500	27·7	12·9
10 to 14	32600	20·8	16·4
15 to 19	18800	12·0	13·4
20 to 24	12800	8·2	11·8
25 to 29	7500	4·8	8·5
30 to 39	8900	5·7	12·5
40 to 49	4300	2·7	8·0
50 and over	4700	3·0	13·4
	156900	100·0	100·0

Winter Milk Campaign. The winter milk campaign is, perhaps, the most outstanding feature of the milk production effort. Before the war, demand for milk was, in every month, less than supply ; even in November and December there was a small quantity surplus to liquid requirements, which was manufactured.

An essential feature of the winter milk campaign has been a considerable turnover from spring to autumn calving ; and this means additional problems in management for the dairy farmer, especially in feeding and breeding. Already much has been achieved :

SALES OF MILK OFF FARMS IN DECEMBER

December	*Million gal.*
1939	76·5
1941	73·0
1943	84·1
1945	92·0
1946	97·0

The steady increase in milk production has now (1954) caught up with demand, the latter having fallen slightly in 1953-54, presumably due to the rise in prices consequent on the reduction of the food subsidies. The problem of the dairy industry as a whole now thus becomes the absorption of the total production, rather than an increase in production. The proportion of milk manufactured will now inevitably increase, and butter and cheese will no longer be rationed.

See Agriculture; Costings; Milk marketing; Utilisation.

Refs.: Milk Production, Reports Nos. 1, 2, 3 and 4, M.M.B.; Williams; Anon. (1947), *MI*, **27**, (12) 55.

PRODUCTION OF MILK IN OTHER COUNTRIES. *See* World production.

PRODUCTS, DAIRY. This term includes primarily butter, cheese, milk powder, condensed and evaporated milk, whey and whey paste and powder, skim-milk.

In a broad sense it also includes cultured milks, processed cheese, casein, casein plastics, etc.

Such materials as ice cream may be considered as dairy products when they contain some constituents of milk.

PROOF SPIRIT. A mixture of alcohol and water which at 51° F. weighs $\frac{12}{13}$ as heavy as water. It contains 49·28 per cent. alcohol by weight and 57·1 per cent. by volume.

PROPIONIC ACID. The third member of the fatty acids series, $CH_3 . CH_2 . COOH$, propionic resembles acetic acid in smell and many of its properties (*see* Fatty acids). In dairying it is important as a flavour constituent in cheese, especially in Gruyère or Emmenthal cheese (p. 192) in which the carbon dioxide causes the holes or eyes. Propionic acid (8 per cent.) is also used to prevent mould growth where such materials as zinc chloride cannot be used.

PROPIONIC ACID BACTERIA (PROPIONIBACTERIUM). This genus is characterised by the following properties: Gram-positive rods of varied morphology, non-motile, non-spore-forming, slow in growth, fermenting sugars, etc., to propionic and acetic acids and carbon dioxide, catalase-positive and tendency to anaerobiosis (an interesting and unusual combination of properties), optimum temperature about 30° C., grows best with yeast extract and lactate or fermentable carbohydrates. (Table Pro. 1.)

From the dairying point of view, this genus is chiefly of interest in relation to the high-scald cheese of the " eye " type (Gruyère). All types are found in dairy products and do not seem to occur elsewhere.

Refs.: Bergey; Hammer; Orla-Jensen; Prescott and Dunn; van Niel (1928), *The Propionic Acid Bacteria*; Haarlem; Kambar *et al.* (1952), *JDS*, **35**, 915 (isolation).

PROPIONIC ACID FERMENTATION. This is the main fermentation in Gruyère or Emmenthal cheese and is represented by the equation

$$\underset{\text{lactic acid}}{3C_3H_6O_3} \rightarrow \underset{\text{propionic acid}}{2C_2H_5 . COOH} + \underset{\text{acetic acid}}{CH_3 . COOH} + \underset{\text{carbon dioxide}}{CO_2} + H_2O$$

Various schemes for this fermentation have been suggested but it is probable that the stages are essentially the same as for the lactic acid fermentation, *i.e.* the hexose is phosphorylated, splits into phosphoglyceric acid and glycerophosphoric acid, the former then passing through pyruvic acid and instead of being reduced to lactic acid, being partly reduced to propionic acid and partly decarboxylated to acetaldehyde, which in turn is oxidised to acetic acid.

Refs.: Prescott and Dunn; Stephenson; Johns (1951), *JGM*, **5**, 326 (mechanism); Kiuru (1949), *IDC*, **2**, 499.

PROSECUTIONS. Milk vendors are liable to prosecution for any infringement of the Food and Drugs Acts. Repeated failure to comply with any of the requirements of the Milk (Special Designations) Orders usually results in the withdrawal of the licence to sell that particular designation of milk. The dairyman is very vulnerable on a number of points and local authorities usually exercise a very reasonable attitude over occasional lapses.

TABLE Pro I

Classification of Propionic Acid Bacteria

Species	*Morphology*	*Pigment*	*Xylose*	*Rhamnose*	*Arabinose*	*Lactose*	*Sucrose*	*Maltose*	*Raffinose*	*Dextrin*	*Starch*	*Glycogen*	*Mannitol*	*Sorbitol*
P. freudenreichii	Short, rounded	Creamy				0	0	0						
P. shermanii	Short, rounded	Creamy				+	0	0						
P. rubrum	Short diphtheroids	Red brown					+	+	+				+	0
P. thönii	Short diphtheroids	Red brown					+	+	0				0	+
P. zeae	Short diphtheroids	Cream		+	+		+	+						
P. petersonii	Short diphtheroids	Orange-yellow					+	+						
P. jensenii [1]	Short diphtheroids	Orange-yellow								0	0	0		
P. raffinosaceum [2]	Short diphtheroids	Orange-yellow								0	0	0		
P. technicum	Short diphtheroids	Orange-yellow								+	+	+		
P. arabinosum	Irregular	Orange-yellow	0	0	+									
P. pentosaceum	Irregular	Creamy	+	+	+									

Does not ferment cellobiose and salicin.

[2] Ferments cellobiose and salicin.

The most frequent causes of prosecutions are, (i) adulterated milk (added water) ; (ii) failure to keep bottles in a state of thorough cleanliness ; (iii) broken glass in bottles.

Troubles under (ii) are largely due to misuse of bottles by customers and local authorities could usefully help by warning and, where necessary, prosecuting persistent offenders. *See* Adulteration ; Freezing-point test ; Legal aspects.

PROTEASES. A general term for enzymes attacking proteins. *See* Enzymes (Erepsin, Pancreatin, Pepsin, and Trypsin).

PROTECTIVE COATINGS.

Refs.: Fischer and Bobalek (1954), *Organic Protective Coatings*, London; Burns and Schuh (1939), *Protective Coatings for Metals*, London.

PROTEIN DEGRADATION PRODUCTS. When proteins such as casein are digested or broken down by proteolytic enzymes or proteases, various enzymes act on the substances formed at successive stages of disintegration. These substances are given names of a general character, and it should be realised that this differentiation is largely arbitrary, being decided mainly by the size of the molecule and also to some extent by the type of enzyme acting on it. The following scheme summarises the general conception :

Proteins
↓ *Proteinases* (*Pepsin*, etc.)
Proteoses
↓ *Proteases* (*Trypsin*, etc.)
Peptones
↓ *Proteases* (*Trypsin*, etc.)
Polypeptides
↓ *Polypeptidases* (*Erepsin*, etc.)
Peptides
↓ *Dipeptidases*
Amino acids

The maturing of cheese is largely the conversion of casein into its degradation products (*see* above) which contribute to the increased digestibility, aroma, and waxy body, the last possibly by actual chemical combination between the fatty and protein complexes. *See* Digestion ; Enzymes.

Refs.: Davies; Richmond; Rogers ; Block (1951), *JDS*, **34**, 1.

PROTEIN EQUIVALENTS. *See* Feeding.

PROTEINS. Proteins may be defined as complex organic compounds containing carbon, hydrogen, oxygen, and nitrogen and sometimes sulphur, phosphorus or other elements. They yield amino acids (p. 51) on hydrolysis and are the essential constituents of all living tissue.

Refs.: Davies; Rogers; Richmond; Sahyun (1948), *Proteins and Amino Acids in Nutrition;* Heinemann and Parker (1951), *JDS*, **34**, 427 ; McMeekin (1952), *JMFT*, **15**, 57.

PROTEOLYSIS. The digestion or breaking down of complex proteins by enzymes (*e.g.* pepsin, trypsin, and erepsin) or by acids or alkalis, or by heat. *See* Digestion ; Enzymes.

PROTEOLYTIC FLAVOURS. Certain types of rather unpleasant flavours in butter, etc., are known as "proteolytic" because they are attributed to the breakdown of proteins and amino acids. The last by decarboxylation give rise to amines. *See* Flavours.

PROTEOSES. The first stage of breakdown of protein molecules. *See* Digestion ; Enzymes ; Protein degradation products.

PROTEUS. This genus of Gram-negative, highly motile, powerfully proteolytic rods is characterised by high pleomorphism, filamentous and curved cells as well as involution forms being common in young cultures, and by the moist, large, amoeboid colonies.

The species nearly all attack gelatin and other proteins rapidly, ferment glucose but not lactose. They occur in decomposing animal remains, soil, faeces, and sewage. Although not directly responsible for human disease, they occur in large numbers in the intestinal canal in cases of summer diarrhoea.

Type species : *P. vulgaris*. *See* Classification.

Refs. : Bergey ; Wilson and Miles.

PSEUDOMONAS. A genus of Gram-negative, actively motile, non-spore-forming rods, attacking proteins strongly and forming a water-soluble greenish pigment. The species occur in water, especially in ponds, etc., and grow well at low temperatures.

They can cause a stinking taint in clean milk held at low temperatures, and taints in butter, to which they may attain access *via* bad quality water.

Type species : *Ps. aeruginosa* (*B. pyocyaneus*). *See* Classification.

Refs. : Bergey ; Wilson and Miles ; Haynes (1951), *JGM*, **5**, 939.

PTYALIN. An enzyme in saliva which digests starch. *See* Enzymes.

PSYCHROPHILIC BACTERIA. The term "psychrophilic" means literally *cold-loving* but it would be more correct to describe these types as *cold-enduring*, as although they can grow at low temperatures, *e.g.* 32° to 40° F. they usually grow faster at 60° to 70° F.

The most common types are *Pseudomonas* and *Flavobacterium*.

Biochemically they attack protein and fat rather than sugars, hence milk held at low temperatures goes putrid rather than sour.

Refs.: Hammer; Rogers; Davis (1951), *SAB*, **14**, 216; Thomas and Chandra Sekhar (1946), *SAB*, p. 47.

PULTOST. *See* Cheese, p. 199.

PUMPS. Pumps are used in dairying for (i) transferring milk from the tipping tank to a storage vessel ; (ii) forcing milk through a cooling or pasteurising plant ; (iii) transferring milk to a road or rail tanker ; (iv) transferring milk from one storage vessel to another (*e.g.* in "blending" milks of different chemical qualities) ; (v) emptying a road or rail tanker.

Pumps are usually of the centrifugal type and stainless steel is now being increasingly used. Pumping should be kept to a minimum because of the following disadvantages: (i) expense; (ii) the churning effect tends to homogenise the fat and so reduce cream line; (iii) the agitation also breaks up clusters of bacteria and so reduces keeping quality; (iv) pumps are difficult to keep clean and are a common cause of bacterial contamination of milk, raw and processed.

It is good design to use gravity for milk flow whenever possible, but speed of operation often requires pumping even when gravity flow might be used.

Fig. Pu 1 shows a centrifugal pump and Fig. Pu 2 a rotary pump.

Table Pu I gives the speed of water through pipes of various diameters for different rates of flow in gal. per min. and Table Pu II values for the required head for given rates of flow for various sized pipes.

Milk at 160° F. has about the same viscosity as water at 60° F.

Other types of pump are sometimes found, *e.g.* positive pumps of the reciprocating type where constancy of flow is essential, and diaphragm pumps in small dairies where the load is light. *See* Management of creameries.

PURIFICATION OF BACTERIAL CULTURES. *See* Classification ; Coliforms ; Lactic acid bacteria.

TABLE Pu 1

SPEED OF LIQUID THROUGH PIPES [1]

Pipe Dia.	Speed of liquid—ft. per sec.									
	1	2	3	4	5	6	7	8	9	10
	No. of gal. per min.									
In.										
1	2·1	4·1	6·1	8	10·5	12·5	14	16	19	21
1½	4·6	9·2	13·8	18·4	23	28	32	37	42	46
2	8·2	16·3	24·5	32	41	49	58	66	74	81
2½	12·7	25·4	38·1	50·8	63	76	90	102	115	127
3	18·5	36·6	55·0	73	90	110	130	145	165	185
4	33	65·2	97·9	131	165	195	230	265	295	330
5	51	102	153	204	255	305	360	410	460	510
6	74	147	220	294	370	440	510	590	660	740
7	100	200	300	400	500	600	700	800	900	1000
8	130	261	392	522	655	785	910	1050	1175	1300
9	165	330	496	660	830	1000	1150	1320	1500	1650
10	204	408	612	816	1020	1224	1428	1632	1836	2040
12	294	588	882	1175	1472	1736	2030	2325	2620	2915
14	400	800	1200	1600	2000	2400	2800	3200	3600	4000
15	461	922	1383	1844	2305	2766	3227	3688	4149	4610
16	520	1040	1560	2080	2600	3120	3640	4160	4680	5200
18	662	1325	1988	2650	3313	3975	4638	5300	5963	6626
20	820	1640	2460	3280	4100	4920	5740	6560	7380	8200
22	990	1980	2970	3960	4950	5940	6930	7920	8910	9900
24	1175	2340	3515	4680	5887	7065	8242	9420	10957	11775
27	1491	2982	4473	5964	7455	8946	10437	11928	13419	14910
30	1837	3675	5513	7350	9187	11025	12862	14700	16538	18375
33	2227	4455	6683	8910	11137	13365	15592	17820	20047	22275
36	2625	5250	7875	10500	13125	15750	18375	21000	23625	26250
39	3110	6220	9330	12440	15550	18660	21770	24880	27990	31100
42	3600	7200	10800	14400	18000	21600	25200	28800	32400	36000
45	4125	8250	12375	16500	20625	24750	28875	33000	37125	41250
48	4720	9440	14160	18880	23600	28320	33040	37760	42480	47200
54	5940	11880	17820	23760	29700	35640	41580	47520	53460	59400
60	7365	14730	22095	29460	36825	44100	51555	58820	66295	73650

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[1] Data from Morton Ltd.

TABLE Pu II TABLE GIVING HEAD NECESSARY TO DELIVER A GIVEN NO. OF GAL. OF WATER PER MIN. THROUGH VARIOUS SIZED PIPES

Gal. per min.	1 *in.*	2 *in.*	3 *in.*	4 *in.*	5 *in.*	6 *in.*	7 *in.*	8 *in.*	9 *in.*	10 *in.*	12 *in.*	14 *in.*	15 *in.*	16 *in.*	18 *in.*	20 *in.*	22 *in.*	24 *in.*	30 *in.*
15	1·02																		
20	1·64	0·051																	
55		0·392	0·051																
80		0·823	0·108																
120			0·243	0·057															
180			0·549	0·131															
200				0·160	0·052														
300				0·361	0·118														
350					0·061	0·064													
500					0·329	0·132	0·061												
700						0·259	0·120												
750						0·297	0·137	0·0706											
900							0·198	0·101											
1000							0·244	0·125	0·069										
1150								0·180	0·100										
1300								0·212	0·117	0·069									
1600									0·178	0·105									
2000										0·164	0·066								
2200										0·199	0·080								
2800											0·129	0·050							
3000											0·148	0·0688	0·0487						
3500												0·0954	0·0677	0·0495					
4000												0·122	0·0867	0·0627					
4500													0·1108	0·0804	0·0446				
5000													0·135	0·0981	0·0544				
5300															0·0630				
6500															0·0927	0·0546			
7000															0·107	0·063	0·040		
8500																0·094	0·600	0·0374	
10000																	0·081	0·0516	
10600																		0·0550	0·0194
12000																		0·0744	0·0243
14500																			0·0356

To find the required head, multiply the length of pipe in yards by the figure in the table for the given pipe and quantity of water required; the result is the head in ft.

Example.—Head in ft. required to pass 1000 gal. of water per min. through 30 yd. of pipe. In table, under 8 in., and in line with 1000, will be found 0·125; 0·125 × 30 = 3·75, which is ft. head required.

The above figures are true for plain, smooth, straight pipes. Additional head must be allowed if pipes are at all of a rough nature or broken in contour internally. For each right-angle bend having a radius of about twice the diameter of pipe, and passing the average quantities given in table, about 1½ in. of additional head must be allowed.

The above figures are from rules given in *Hydraulics* by Thomas Box.

PUS. The thick, yellowish fluid contained in boils, abscesses, etc. It is rich in leucocytes and their ingested bacteria.

PUTREFACTION. The decomposition of animal remains, and especially the protein part, by bacteria. True putrefaction can only occur at neutral or mildly alkaline reactions and is characterised by the decarboxylation of amino acids to amines and diamines, such as putrescine $NH_2 . (CH_2)_4 . NH_2$, sulphuretted hydrogen H_2S, and other foul-smelling substances.

On account of the lactose in milk and its products and the ubiquity of the lactose-fermenting lactic acid bacteria, putrefaction is virtually impossible in dairy products, only occurring in such special instances as very ripe cheese of the Limburger and other types which ultimately attain a high *p*H with a high moisture content. *See* Stability.

Ref.: Stephenson.

PUTRID BUTTER. A most objectionable fault in butter due to the growth of those Gram-negative organisms which attack protein putrefactively. *See* Butter ; Putrefaction ; Rabbito ; Stability.

Ref. : Hammer.

Q

Q FEVER. A disease caused by *Rickettsia burneti*, a very small organism between bacteria and viruses in size. Outbreaks have occurred in Devon and Kent through excretion of the organism by cows in their milk. The organism is rather heat-resistant, but appears to be killed by H.T.-S.T. pasteurisation, although the margin of safety is small.

Refs.: Derrick (1953), *Med. J. Austral.*, **1**, 245; Huebner *et al.* (1948), *Publ. Hlth. Rep. Wash.*, **63**, 214; (1949), **64**, 499; Marmion *et al.* (1951), *MBMH*, **10**, 119.

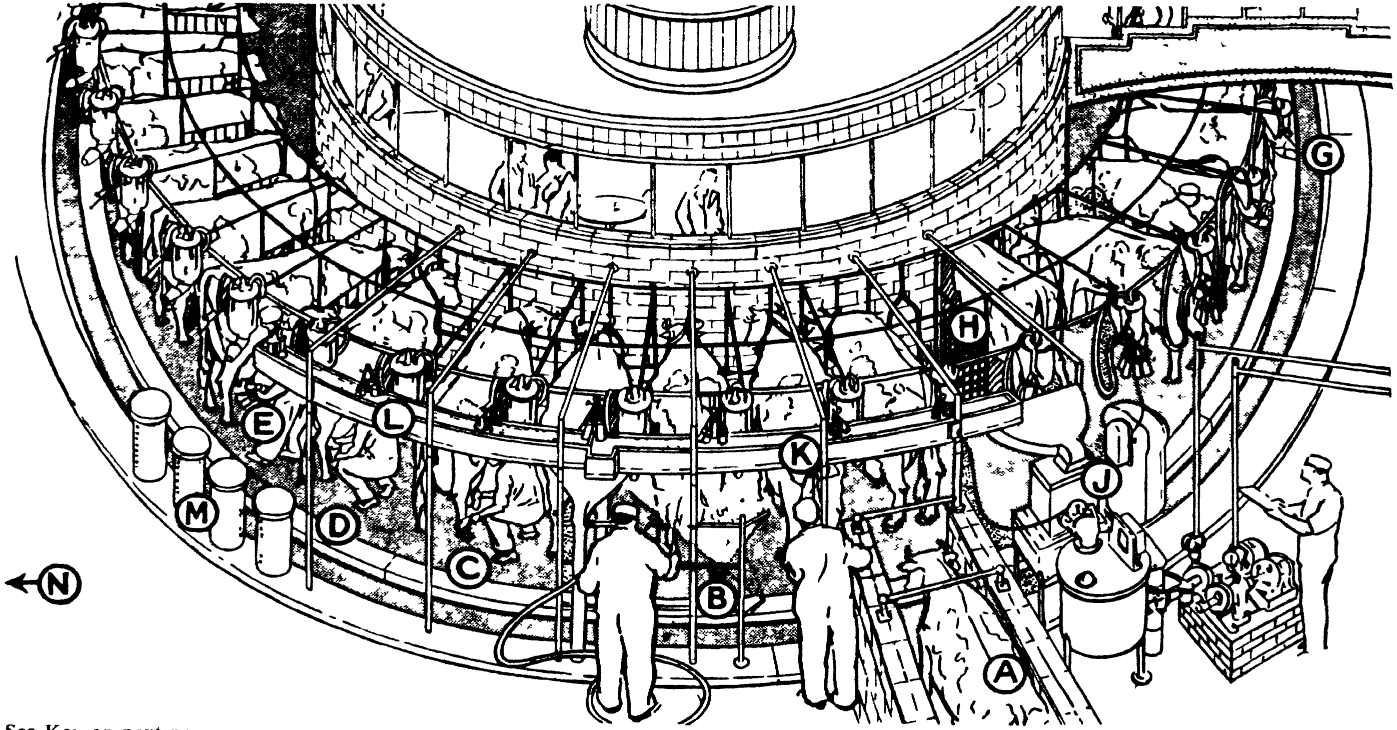
QUALITY. (i) **Milk.** The term quality is used in two different senses and may mean either chemical (fat and solids-not-fat) or bacteriological keeping quality. It is therefore advisable always to define quality by the appropriate prefix (*see* Bacteriological grading of milk; Composition; Quality payment). Less frequently, the word quality may be used in the more strictly medical sense (*see* Diseases) or veterinary sense. *See* Abnormal milk; Mastitis.

(ii) **Butter, Cheese, etc.** With milk products the term quality is generally used in relation to those properties taken into account in grading (p. 491) and statutory requirements. *See* Butter; Cheese; Condensed and evaporated milk; Legal aspects; Milk powder; Rheology.

QUALITY MILK PRODUCTION. The drive for quality milk in this country has come from a few individuals like the late Stenhouse Williams and Wilfred Buckley, a few progressive producers and a few progressive buyers. A small percentage of farmers still produce milk of a quality that should not be tolerated, and conditions on some farms are lamentable. One of the worst mistakes ever made in the industry was to guarantee a market for any milk without a quality specification. During the last 12 years the efforts of the National Milk Testing Scheme (p. 754) and the Joint Milk Quality Control Scheme (p. 565) have led to some improvement.

One of the best milk-production centres in the country is that established by Dr. Chalmers-Watson in Drem in East Lothian. In this system milk is conveyed from the two 6-point Auto-Recorder machines in the lactory through heat-resisting glass pipes and special strainers, to the dairy (Fig. QM 1). Each Auto-Recorder machine has its own releaser, set high over the large cooler. The cooler is encased in a dust-proof cabinet, which acts as its own sterilising chest, and is connected to a refrigerator. From the cooler the milk passes to an automatic capping and bottling machine, untouched by hand and within a few minutes of leaving the cow (Fig. QM 2). Part of the yield undergoes ultra-violet ray treatment in a special room to which it is directed. Adjoining the dairy is a laboratory, where samples of milk are tested for bacterial count and for butterfat. There is a glass observation room set above and between the lactory and dairy, from which the various operations of hygienic milk production can be observed.

Quality Milk in U.S.A. The Walker-Gordon laboratories have been investigating problems concerned in the production of an ideal milk for over 40 years. The most spectacular feature is the Rotalactor, invented by H. W. Jeffers, which is a giant rotary milking unit 60 ft. in diameter, holding 50 cows, and moving at a rate of 15 ft. a min. (Fig. QM 3). On this 240 cows are washed, dried, " disinfected ", and milked every hour—a complete herd of 1680 cows in 7 hr. The Rotalactor is housed in a lactorium in which temperature and humidity are controlled. All workers are under medical supervision. Not only the milking but the feeding of the cows is scientifically studied and controlled in order to maintain the cows in health and enable them to produce a milk of high vitamin content. A typical daily ration is as shown on page 866.



See Key on next page

[By courtesy of Alfa Laval Ltd

FIG QM 3 —*Rotalactor. Diagram Showing how the System Works*

A. *The cows step on to the moving platform.*

B. *The cows are washed almost automatically.*

C. *Each cow's udder is wiped off with two individual sterilised towels.*

D. *Milk samples from each quarter of the cow's udder examined by drawing it on a fine-mesh copper strainer.*

E. *The milking machines are put on.*

G. *The milking machines are taken off here.*

H. *The cows step off the platform and go back to their barns.*

J. *The milk is automatically dumped from the Pyrex jars, weighed and piped to the bottling room.*

K. *The milking machine is thoroughly rinsed in cold water.*

L. *The milking machine is sterilised by hot water before being used on another cow.*

M. *Modern air-conditioning plant controls temperature, regulates humidity, and cleanses the air.*

N. *The platform moves 15 ft. per min. in this direction and completes a revolution in 12½ min.*

Pressing a button starts and stops the Rotolactor.

Foodstuff	*lb.*	*Specially supplying*
Corn silage	24	Carbohydrate and protein
Lucerne	13	Carbohydrate and protein and vitamin A
Dehydrated lucerne hay	8·5	Carbohydrate and protein and vitamin A
Grain mixture	13	Carbohydrate and protein
Oats	2	Carbohydrate and protein
Bran	1·5	Carbohydrate and protein
Corn	1·5	Carbohydrate and protein
Barley	1·5	Carbohydrate and protein
Molasses	1·5	Carbohydrate
Babassa meal	1	
Linseed meal	1	Oils
Malt sprout	0·8	B vitamins
Gluten feed	0·5	
Distillers' grain	0·5	B vitamins
Brewers' grain	0·5	B vitamins
Soya-bean meal	0·5	
Salt	0·2	
Irradiated yeast	0·2	Vitamin D
Minerals	0·1	

There are four Walker-Gordon certified milks : plain raw, pasteurised, vitamin D (containing at least 400 U.S.P. units per quart), and homogenised. The last is very easily digested on account of the small fat globules and low curd tension.

QUALITY PAYMENT. The question of quality payment for milk is one of the most controversial questions in the dairy industry. Broadly speaking, most persons qualified to express an opinion think that there should be some system of quality payment, but it is difficult to get any agreement as to how payment should be made.

Table Q I summarises the problems which have to be solved before any system can be inaugurated.

TABLE Q I

FUNDAMENTAL ASPECTS TO BE CONSIDERED IN RELATION TO QUALITY PAYMENT

(1) The value of the different properties of milk to the community.
(2) The meaning of quality payment. Requirements of any scheme.
(3) The advantages of and justification for quality payment.
(4) The disadvantages of and objections to quality payment.
(5) What does the buyer want ? Methods of utilising milk.
(6) The choice of properties as the basis for quality payment.
(7) Methods of testing and number of grades to be employed—Chemical and bacteriological.
(8) Methods of calculating payment.

The Economic Structure of the Dairy Industry. There are two main ways of organising the sale of milk, free buying and selling, and a nationally-controlled scheme. The first was in force in this country prior to the founding of the Milk Marketing Board in 1933. Obviously with such a system any buyer could pay any premium he liked for any given quality in the product, and could make a corresponding charge to any consumer who was prepared to pay the price. Grades were officially recognised from 1921 onwards and in 1922 four grades were defined, these being concerned with bacterial count and freedom from *B. tuberculosis*. The advent of the Milk Marketing Board first made possible a national scheme for payment on quality. National marketing now makes possible almost any scheme of quality payment, as far as the producer and distributor are concerned, provided both parties are agreeable.

The Present Price Structure. This is illustrated in Table Q II and shows a maximum price differentiation of 4d. gal for freedom from one disease (tuberculosis) and of 4d. gal. for richness in chemical composition (Channel Islands milk). Until recently, T.T.(F.B.) milk, which could be, and sometimes was, of very poor nutritional value, was sold retail for 5s. 4d. gal., while rich milk (not sold as Channel Islands) of low bacterial content would command only the standard price (about 3s. 4d.). It is a curious anomaly that even to-day good keeping quality as such, which is perhaps the most important commercial property of milk, commands no premium.

TABLE Q II

QUALITY PAYMENTS IN FORCE JANUARY, 1954

Type of milk	*By Milk Marketing Board*			*By buyer*	*Extra payment by consumer*
	Wholesale -P	P-*retailers*			
		P-*retailers*	*Payable to Board*		
Attested only	2d.	⅜d.	—	—	—
Accredited only	1¼d.	—	⅝d.	—	—
Accredited and Attested	3¼d.	1⅜d.	—	—	—
T.T. only	2d.	⅜d.	—	—	4d. (past.)
T.T. and Attested	4d.	2⅜d.	—	—	4d. (past.)
Ordinary T.T. (Farm-bottled)	—	⅜d.	—	By arrangement	12d.
Channel Islands (over 4 per cent. fat)	—	—	—	4d.	8d.

The Value of the Different Properties of Milk to the Buyer and the Consumer. To be a satisfactory article to the consumer, milk must fulfil the following conditions : (i) it must be of adequate keeping quality ; (ii) it must be free from disease-causing organisms ; (iii) it must be of attractive appearance and of as high nutritional value as possible ; (iv) it must be pure, unadulterated and free from foreign bodies and visible dirt.

The producer and the buyer or distributor have a joint responsibility for all four aspects. Keeping quality and chemical composition or nutritional value are determined by the producer. The buyer can improve keeping quality and kill all disease organisms by efficient pasteurisation. He can remove foreign objects and visible dirt by efficient filtration, but cannot subtract added water, the soluble constituents of manure and the bodies of bacteria, although he can render the last harmless.

On the other hand, the distributor can very easily reduce the keeping quality of milk, even if it is pasteurised, and slight overheating will have a marked effect on cream line, although the effect on the nutritional value of the milk will be negligible.

It is of interest to consider the constituents of milk from the point of view of their usefulness to buyer and consumer. The average composition of milk is given in Table NV I (p. 759) and Table NV III (p. 761) shows the approximate percentage contribution of 1 pint of average milk to the daily diets of an adult and a 5-year old child. It is evident that milk is chiefly valuable as a source of calcium, riboflavin (part of vitamin B_2), and protein. All these constituents are to be found in the solids-not-fat. Milk is also a useful source of vitamin A, B_1, and C and of calories or energy, the last in spite of its water content of nearly 88 per cent. Since the object of quality payment is to maintain or improve the quality of milk, it is pertinent to enquire how these and other properties vary in milk. This aspect is illustrated in Table Q III, from which it will be seen that fat, protein, calcium, and vitamin A are of particular interest because they are nutritionally important and variable. There is, therefore, on nutritional grounds, a good case for any system which will tend to maintain a high concentration of these substances in milk. Moreover, there is a good case for artificially maintaining the composition of milk at a uniform level in summer and winter. In Sweden the fat content is standardised and vitamins are added in winter.

TABLE Q III

THE VALUE OF MILK TO THE COMMUNITY

	Variability (in single herds)	*Importance*
Bacteriological qualities :		
Keeping quality	+ + + +	+ + +
Freedom from taint	+ + +	+ +
Chemical qualities :		
Fat	+ + + +	+ +
Protein	+ +	+ +
Lactose	+ +	+
Calcium	+ +	+ + +
Other minerals	+	+
Vitamins:		
A	+ +	+ +
B_1	—	+ +
B_2 complex	+	+ + +
C	—[1]	+ +
D	+ + +	(+)

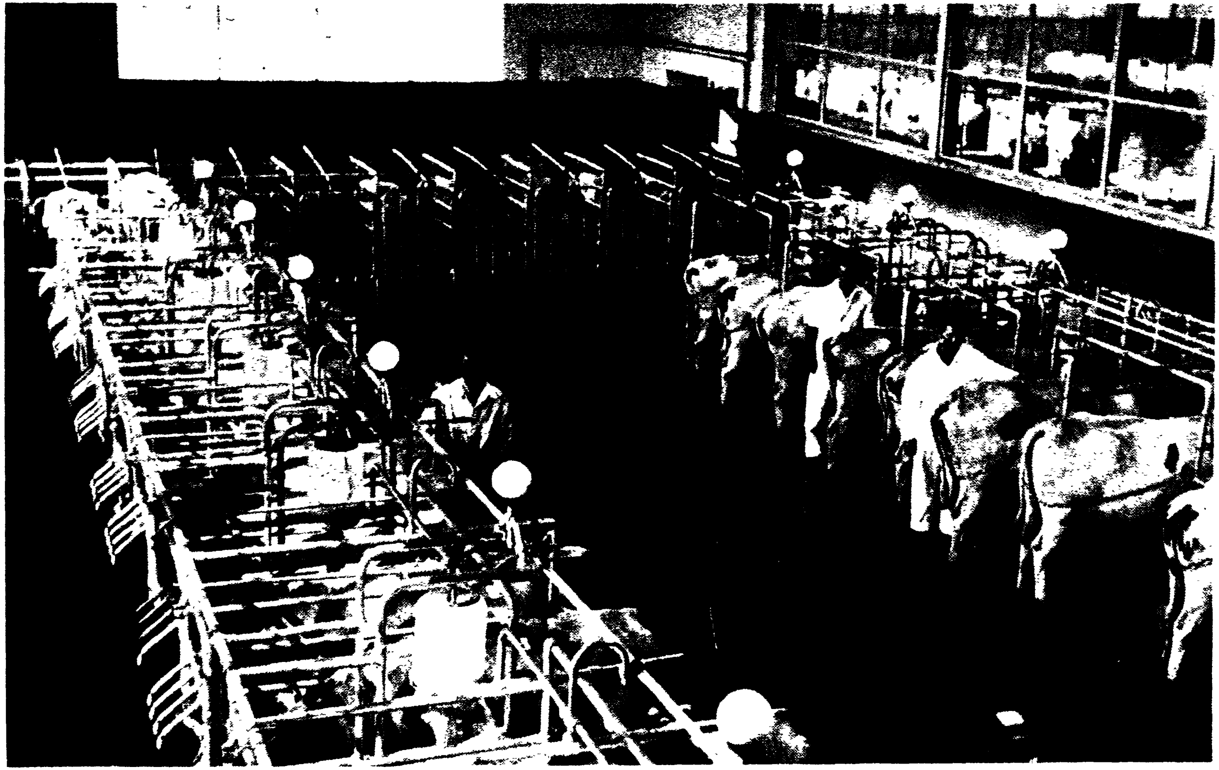
[1] Vitamin C in milk can be destroyed by exposure to sunlight.

— = practically constant.

+, + +, etc. = increasing variability.

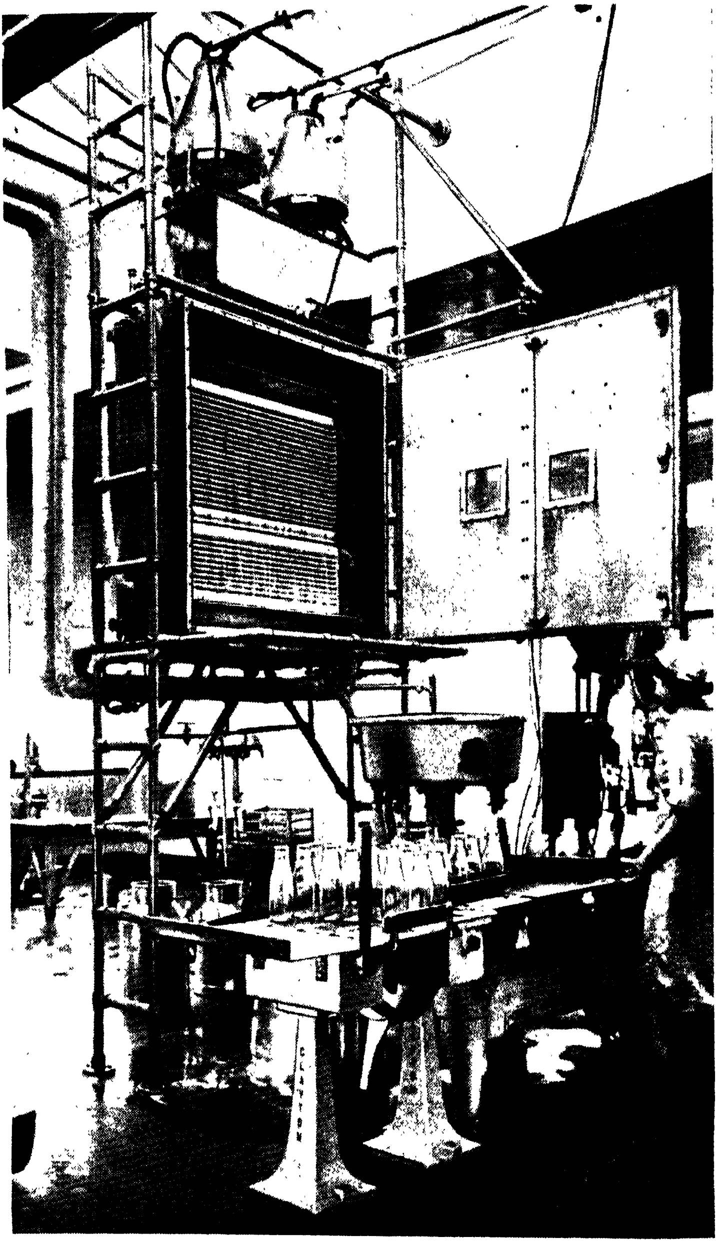
The Meaning of Quality Payment. Quality payment may be defined as a system of payment in which the price paid to the producer varies according to defined qualities of the milk. Usually nutritional value or chemical composition and bacteriological quality, measured by the numbers of bacteria or keeping quality, are the qualities considered.

It is not possible to decide which is the more important of the two. Both are equally important properties to the consumer, although under present conditions the buyer is interested only in keeping quality if the milk is for liquid sale.



[By courtesy of Dr. Chalmers Watson.

FIG. QM 1.—*Quality Milk Production.*



[*By courtesy of Dr. Chalmers Watson.*

FIG. QM 2.—*Automatic Bottling and Capping of Milk, Untouched by Hand.*

Qualities in milk are of two kinds, the " all or nothing " type of quality like that designated as " Tuberculin Tested " or " Channel Islands ", which are precisely defined grades, and the continuously variable qualities like fat content and keeping quality. It follows that while the first type of quality can be recognised by a clear cut payment, *e.g.* 4d. a gal. extra, the second type must be assessed either by an infinitely variable sliding scale or by arbitrary classification.

Any scheme to be universally acceptable must satisfy certain requirements in the way of practicability, justness, and the object it achieves. Table Q IV outlines suggested basic requirements for any scheme of quality payment.

TABLE Q IV

Basic Requirements of a Quality Payment Scheme

(1) The basis of the scheme must be fair, simple and easily understood.
(2) All producers must be included in the scheme, and the scheme must be acceptable to the majority of them.
(3) All milk must be bought by the Government or its agent and re-sold to distributors and manufacturers at rates dependent on the value of the milk for the particular purpose in view.
(4) Both chemical (or nutritive) and bacteriological (or keeping quality) aspects of milk must be taken into account in the scheme.
(5) The basis of testing must be fair to the producer, distributor, and consumer.
(6) The cost of testing must be as low as possible.
(7) All testing, interpretation, and calculations must be made by competent and un biased personnel.
(8) All results should be made available to the producer as soon as possible.
(9) An adequate advisory service must be available to assist immediately any producer asking for help.
(10) Price differentiation must be sufficient to discourage strongly the production of bad milk and encourage the production of good milk.
(11) There should be the minimum number of grades and differential prices for the consumer, *e.g.* :

Standard milk. Milk from T.T. herds, efficiently pasteurised and with a *minimum* keeping quality of 24 hr. from the time of delivery.

Channel Islands milk. As Standard but from Channel Islands herds and with a minimum fat content of 4·5 per cent. (or according to the season).

Super milk. As Channel Island but produced under special conditions and with a super-keeping quality.

The problem of the producer-retailer. It might appear that the producer-retailer presents an unsolvable problem for any national scheme of quality payment, but this is not so. The producer-retailer already pays or receives special monies according to the designation of his milk, and there is therefore no reason why this system should not be extended to chemical and bacteriological qualities. The producer-retailer's milk could be sampled just like any other producer's and adjustment in payment made according to the results of the tests.

The Significance of Quality Payment to the Consumer. There is no reason why quality payment should result in the ordinary consumer paying more for his milk.

For the general public we should aim at a milk of 4 per cent. fat and 9 per cent. solids-not-fat (average values) from T.T. herds, efficiently pasteurised, and with a keeping quality of *at least* 24 hr. from the time of delivery under the most unfavourable conditions. There might be a case for a high-fat Channel Island milk at a special price, and possibly for a high-fat milk of extra long keeping quality, such as might be obtained by efficient " in-bottle " pasteurisation. Apart from these two possible exceptions, there should be only one price to the consumer.

The Justification for Quality Payment. Let us consider the present position in relation to the two outstanding commercial properties of milk, chemical composition and keeping quality.

Chemical composition. There are three facts that must be considered under this aspect: (i) Milks from different herds and especially from different breeds differ markedly in chemical composition. The fat is the most variable major factor, altering about 2½ times as much as the solids-not-fat. (ii) It costs more to produce high-fat milk than ordinary milk. (iii) The chemical composition of bulk milk has fallen slightly through a variety of causes, among which breeding for quantity without regard for quality, decreased manufacture,[1] poor quality and inadequate quantity of winter feeding stuffs and mastitis are prominent.

Analytical figures for the milk from the various breeds vary according to the source of information, but all the data agree that of the five major breeds in this country, the Jersey and Guernsey cows indisputably yield the richest milk, followed by the Ayrshire, Shorthorn, and Friesian. Typical figures are given in Table Q V. *See* also Breeding.

TABLE Q V

TYPICAL FIGURES FOR THE AVERAGE COMPOSITION (%) OF MILK OF FIVE BREEDS OF COWS

Breed	*Water*	*Total solids*	*Fat*	*Protein*	*Lactose*	*Ash*
Guernsey . . .	85·13	14·87	5·19	4·02	4·91	0·74
Jersey	85·31	14·69	5·18	3·86	4·94	0·70
Ayrshire	86·89	13·11	4·14	3·58	4·69	0·68
Shorthorn . . .	87·43	12·57	3·63	3·32	4·89	0·73
Friesian	87·50	12·50	3·55	3·42	4·86	0·68

The cows of this country are mainly Shorthorn and Friesian and relatively few Jersey, Guernsey, Ayrshire, and animals of other breeds.

If the fat and solids-not-fat figures for producers sending in to a typical creamery are examined, a similar frequency distribution is obtained for both fat and solids-not-fat (Davis, 1948, *JSDT*, **1**, 81). It will be seen that 1 per cent. of the producers sent in milk below 3 per cent. fat; 38 per cent., 3 to 3·5 per cent.; 53 per cent., 3·5 to 4 per cent.; and 8 per cent. over 4 per cent. (Channel Islands herds not included). Similarly, 11 per cent. sent in milk below 8·5 per cent. solids-not-fat; 36 per cent., 8·5 to 8·74 per cent.; 47 per cent., 8·75 to 8·99 per cent.; and 6 per cent. over 9 per cent. solids-not-fat.

Now it is only right that this inequality in fat and solids-not-fat contents of herd bulks should be recognised.

What the farmer has to pay for in feeding stuffs and pasture maintenance is not gal. of milk but lb. of milk solids. Thus it usually costs more to produce Guernsey and Jersey milk than Shorthorn, and Shorthorn costs more than Friesian milk gal. for gal. This fact has received local recognition in the past by payment of a fat bonus where the milk was used for cheese or butter manufacture. Thus in Cornwall and other buttermaking areas, a bonus of 0·1d. for every 0·1 per cent. fat over 4 per cent. might be paid. This was better than nothing, but the high fat milk was still bought cheaply, as a 6 per cent. fat milk would only receive 2d. more than a 3 per cent. fat milk and yet make twice as much butter. It is evident that owners of herds producing rich milk have been grossly underpaid for years and that producers of low-solids milk have been relatively slightly overpaid.

Factors responsible for poor compositional quality. It has been claimed that the chemical composition of milk (fat and solids-not-fat) has deteriorated slowly but steadily during the last 20 years. Extensive surveys have been made of the causes of this decline by the National Institute for Research in Dairying and it is concluded that the factors responsible in order of importance are: (i) breeding for quantity without regard for quality; (ii) poor quality (low starch equivalent) and inadequate quantity of winter feed during the war years; (iii) udder disease.

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[1] This is a factor because manufacturers formerly paid a bonus for good chemical quality.

The first is usually coupled with references to Friesian herds and the increasing use of Friesian bulls, especially in districts such as Cornwall which were formerly largely manufacturing areas and where there was an incentive to produce a high-fat milk for buttermaking. The removal of this incentive consequent upon the increased demand for liquid milk has, quite understandingly, encouraged the farmers to breed for high yields and to ignore fat content. Before the war, nearly 30 per cent. of our milk was manufactured, while to-day only about 15 per cent. is so used. There is little doubt that a system of payment which recognised the value of rich milk would result in a return to breeding along the former lines of attention to high fat content. Provided the right strain of bull is used, there is no reason why Friesian herds should not give rich milk. Some Shorthorn herds are also yielding poor-quality milk, but it is extremely rare to find other major breeds failing in this respect.

The second cause is the inevitable consequence of the war and is marked over the period January to April, milk showing a marked rise in solids-not-fat when the cows go out to grass in May. The gradual restoration of the feeding-stuffs position will presumably eliminate this factor.

The third cause, mastitis, is not now considered to be so important quantitatively as formerly, but in badly infected herds it can be a major factor. In the author's experience "notorious" cases of genuine low solids-not-fat are frequently due to a high incidence of mastitis in Friesian and Shorthorn-Friesian herds.

Bacteriological or keeping quality. Producers' milks vary more in bacteriological or keeping quality than in chemical quality. The highest fat content is about 50 per cent., and the highest solids-not-fat only about 10 per cent. above the lowest respective figures. The dirtiest milk accepted may have a plate count of, say, 30,000,000, while the cleanest may be, say, 3000, the *ratio* of the counts being 10,000. If we consider keeping qualities the poorest may be, say, 3 hr., while the best may be, for example, 48 hr. from the time of receipt at the creamery, giving a *ratio* of 16. The frequency distribution of producers according to the routine resazurin test, which measures hygienic quality in a general sense with a considerable weighting by keeping quality, is more even than with chemical quality.

The importance of bacterial or keeping quality to the buyer lies not only in the fact of this very wide distribution but also in the fact that bacterial quality is a *dynamic* property of milk, whereas chemical composition is a *static* quality. In its passage from cow to the consumer, milk does not change in chemical quality in the analytical sense, but its bacterial content changes at an increasing pace after the first few hours (Table Q VI).

It is well recognised in the trade that a little bad milk can turn a large bulk sour. This point is illustrated in Table Q VII, which shows the tremendous effect of as little as 0·1 per cent. bad milk on the keeping quality of the bulk.

Probably about 30 per cent. of dairy farmers are producing milk of really good bacterial quality, about 30 per cent. are not unsatisfactory although they could undergo some improvement, and about 30 per cent. are unsatisfactory, from 5 to 8 per cent. being literally a potential menace to the milk supply.[1] These last, of course, constitute the black list which every efficient creamery manager keeps constantly in mind. Many creameries now test the milk of this 5 to 8 per cent. every day by the 10 min. resazurin test. Typical figures for category distributions in the early days of the National Milk Testing and Advisory Scheme

[1] Until recently much the same classification could be applied to dairies.

TABLE Q VI

Growth of Bacteria in Milk from Time of Milking to Delivery to the Buyer

(Typical Data)

	Time	*Basic proliferation*	*Aseptically produced milk from mastitis-free cows*	*Very clean milk*	*Clean milk*	*Dirty milk*	*Clean milk plus 10% dirty milk*
lag period	4 p.m.	1	100	1000	5000	100,000	15,000
	10 p.m.	1	100	1000	5000	100,000	15,000
logarithmic period	1 a.m.	2	200	2000	10,000	200,000	30,000
	4 a.m.	4	400	4000	20,000	400,000	60,000
	7 a.m.	8	800	8000	40,000	800,000	120,000
	10 a.m.	16	1600	16,000	80,000	1,600,000	240,000
	1 p.m.	32	3200	32,000	160,000	3,200,000	480,000
	4 p.m.	64	6400	64,000	320,000	6,400,000	960,000

TABLE Q VII

Effect of 0·1 per cent. Dirty Milk on Keeping Quality of Various Producers' Milks, Raw and Pasteurised

(Times in min. to reach disc O in the resazurin test)[1]

Producer	*Raw*		*Pasteurised*	
	Milk alone	*Milk plus 0·1 % dirty milk*	*Milk alone*	*Milk plus 0·1 % dirty milk*
8	60	5	about 1000	5
10	15	5	1000	10
12	15	10	500	10
22	15	5	1000	5
23	60	5	1000	5
24	90	15	1000	10
25	15	5	1000	5
28	30	5	1000	5

All samples held at 18° C. for 13½ hr. The dirty milk was a composite of category C milks 24 hr. old.

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[1] This is slightly longer than the methylene blue reduction time. The longer the time, the higher is the quality of the milk.

are illustrated in Table Q VIII. It should be remembered that these category limits were purposely made lenient in war time, category C in hot weather corresponding to a plate count of 10,000,000 or more. Category A may be described as not unsatisfactory, about half of these being really good.

TABLE Q VIII

PROPORTION OF PRODUCERS IN CATEGORIES N.M.T.A.S. (TYPICAL FIGURES)

Mean atmospheric temperature (°F.)	*% Producers in categories*			
	A	*B*	*C*	*B + C*
40 or less	79·7	19·7	0·6	20·3
40 or less	73·5	23·5	3·0	26·5
40 or less	77·0	19·5	3·5	23·0
41	69·8	28·9	1·3	30·2
45 to 50	86·1	10·6	3·3	13·9
45 to 50	80·2	14·3	5·5	19·8
45 to 50	71·5	20·0	8·5	28·5
44	79·8	16·0	4·2	20·2
51 to 60	73·4	16·5	10·1	26·6
51 to 60	73·5	16·0	10·5	26·5

Further advantages of improved chemical quality. Not only is a chemically richer milk of greater nutritional benefit to the nation as a whole, but the economics of milk handling and manufacture would benefit indirectly. Apart from the advantages of improved bacteriological quality, which are so well recognised now that they need no description, improved chemical composition would save money in many ways.

Economic Aspects of Milk Handling in Relation to Nutritional Value. Milk is about ⅞ water and so every year a considerable sum of money is spent in transporting millions of gallons of water about the country. Thus, of 1300 million gal. of milk, about 1140 million gal. is ordinary water. This water not only has to be collected at the farm, loaded on to lorries, taken to depots and cooled, but also has to be taken by rail or road to the great consuming areas, pasteurised, bottled, and distributed to the consumer. Let us take a round figure of 1800 million gal. per annum of milk of average solids content 12·4 per cent. as the desirable milk consumption by the public. A transport charge of 2d. per gal. on this represents £15 million ; a distribution charge of 8d., £60 million ; and a comprehensive handling charge of 1s. per gal., £90 million. If now there is a steady trend towards a milk of solids content just reaching the legal limit of 11·5 per cent. as would happen if milk production were organised purely as a business concern, we should require 1940 million gal. of milk of this quality and the charges would become £16,200,000, £64,800,000, and £97,200,000 respectively, *i.e.* we should spend over £7 million annually more in handling such milk, the total nutritional value remaining the same. If, as the result of quality payment, the solids content were to rise to 13·5 per cent. we should require only 1,650,000,000 gal. of this richer milk and the charges would be £13,750,000, £55,000,000, and £82,500,000 respectively, *i.e.* we should save about £7,500,000 in the working cost of the dairy industry. The difference between the two extremes amounts to nearly £15,000,000 per annum.

At the present time, 1,600,000,000 gal. of milk containing 12·4 per cent. total solids and being bought at 3s. 2d. per gal., contains 900,000 tons of first-class nutrients of 100 per cent. digestibility, for which the farmer receives £250,000,000. An increase of 0·1 per cent. in the average total solids would mean an extra 6250 tons of first class nutrients for the consumer.

Manufacturers would benefit because a richer milk would mean lower manufacturing costs, especially in condensing and drying. For example, let us consider the heat exchange costs of drying 200,000,000 gal. of milk of average composition 12·4 per cent. total solids. This would require the evaporation of 175,200,000 gal. of water to give 256,000,000 lb. milk powder. If the average composition of our milk were to fall to 11·5 per cent. total solids, 216,000,000 gal. would be required to give the same quantity of powder, the amount of water to be driven off being 191,400,000 gal. If, as the result of quality payment, the average total solids were to rise to 13·5 per cent., only 184,000,000 gal. of milk would be required to yield the same weight of powder, the volume of water to be driven off being only 159,000,000 gal. The difference between the two extreme volumes of water is 32,400,000 gal. At a cost of ½d. per gal. of water to be evaporated this is equivalent to £66,000 in evaporation costs alone.

What Does the Buyer Want ? The consumer is affected by all properties of milk, consciously or unconsciously, but the buyer is not concerned, at any rate from the business point of view, with any property which is not apparent to the customer. This point is illustrated in Table Q IX. Quite obviously the customer stands to benefit from a milk which is free from pathogenic bacteria, is of good keeping quality, rich in fat, solids-not-fat and vitamins, etc. If customers are tied to a given distributor, the fat content or cream line makes no difference to his sales, although it was formerly an important sales point. Solids-not-fat and vitamins, etc., never have been of any sales significance. Thus of all the recognised properties of milk keeping quality is easily of the greatest importance to the buyer in the liquid market. Provided milk is comfortably above 3 per cent. fat and 8·5 per cent. solids-not-fat the retail distributor is not further interested in the chemical aspects of milk, apart from cream line, for which the fat content is only one factor. Now (1954) that there is free competition everywhere except in London and Maidenhead, cream-line is once more becoming a " sales point ".

TABLE Q IX

ECONOMIC INTEREST IN PROPERTIES OF MILK FOR LIQUID SALE

	Buyer	*Consumer*
Bacteriological :		
Absence of disease - causing organisms	—[1]	+
Low bacterial count (good keeping quality, pasteurisability) .	+	+
Chemical :		
Fat	+ (competition) — (no competition)	+
Solids-not-fat . . .	—	+
Vitamins, etc. . . .	—	+

[1] The buyer is unable in practice to test milk for pathogens, but by pasteurisation he can ensure safety for the consumer.

When we come to consider the manufacturer, however, chemical composition becomes a much more important matter. This is illustrated in Table Q X. Broadly speaking, the manufacturer wants a milk of low bacterial count for all purposes, but for different types of manufacture he fears different types of fault-producing organisms (Table BG VI, p. 70). But on the chemical side he wants positive qualities—high total solids for milk powder and cheese, and high fat for cream and butter. The yield of his product is directly proportional to the content of the milk in certain constituents as shown in Table Q X, and it would be logical for him to pay for his milk, not on gallonage, but on lb. fat, or fat-plus-casein, or total solids.

What does the buyer require in bacteriological quality? It is not possible to give a simple answer to this question. So much depends on such factors as the season of the year, prevailing atmospheric temperature, times of arrival, local conditions, method of utilisation, required keeping quality of the product, etc. However, although we cannot always define the exact border line, buyers know quite well the class of milk that is good and the class that is bad. There must necessarily be a doubtful zone within which the decision of the buyer must be influenced by the factors mentioned above.

TABLE Q X

QUALITIES IN MILK DESIRED BY THE BUYER FOR VARIOUS METHODS OF UTILISATION

	Chemical	*Bacteriological*
Liquid :		
Raw . . .	Up to legal standards and best possible cream line	Good keeping quality. Absence of taints
Pasteurised . .	,,	Adequate keeping quality in raw state Absence of taints Absence of thermoduric organisms
Sterilised . . .	Up to legal standards	Absence of resistant spore formers
Manufacture :		
Milk powder .	High total solids	Adequate keeping quality
Cheese . . .	High fat plus casein	Absence of organisms producing faults in cheese Chemically normal milk
Butter . . .	High fat	Absence of organisms producing faults in butter
Skim condensed .	High solids-not-fat	Absence of organisms producing faults in condensed milk Chemically normal milk
Cream . . .	High fat	Good keeping quality

It would not be wise, therefore, for the buyer to suggest a minimum standard on arrival, *e.g.* disc 4 on the 10-min. resazurin test, or ½ hr. on the methylene blue test. If all producers sent in milk only just above this standard, then this standard would not be high enough. Any consideration of standards must depend on the frequency distribution of the producers in relation to the quality considered (*cf.* Table Q VIII).

Further, whereas the chemical composition of a bulk is the arithmetic mean

$$A = \frac{x_1g_1 + x_2g_2 + \ldots}{g_1 + g_2 + \ldots}$$ where x = per cent. constituent considered, g = volume of herd bulk,

the bacteriological quality of a bulk milk that has to be held or transported for any length of time is heavily weighted by a small proportion of high count milk (*cf.* Table Q VII, p. 872).

The Choice of Properties as the Basis for Quality Payment. Consideration of Tables Q X and BG V (p. 33) makes it quite clear that the properties desired in milk by the buyer vary according to the method of utilisation. It is essential to have a scheme which is as simple as possible—any attempt to complicate a national scheme by considering the weighted requirements for different methods of utilisation would render the scheme impracticable. We must, therefore, decide on the best single chemical or compositional property, and on the best single bacteriological property. Possible methods are given in Table Q XI.

TABLE Q XI

SUMMARY OF METHODS FOR QUALITY PAYMENT

Chemical:	
Fat [1]	The most common and oldest. Cheap and practicable
Total solids	The most just fundamentally. Cheap and practicable
Calories	Unnecessarily complicated. Too expensive
Fat plus casein [1]	Virtually the same as total solids. More costly
Bacteriological:	
Curd test [1]	Very old method. Sound in practice
Plate count and coli [1]	Expensive
Methylene blue [1]	Cheap and practicable. Not influenced by mastitis
Resazurin (1 hr).	Cheap and practicable. Weighted by mastitis
Keeping quality.	Testing more elaborate than methylene blue and resazurin
Thermoduric count (pasteurisability)	Expensive
Cleanliness:	
Sediment [1]	Cheap and simple. Does not measure keeping quality

[1] Already used in one or more countries.

Chemical aspects. From the practical point of view we are limited to ***fat*** and *total solids* and it is suggested that *total solids* is the best basis for the following reasons: (i) It is the best measure of the nutritional value of the milk. (ii) It is what the farmer has to pay for in producing milk. (iii) It is the best single property for assessing the value of the milk for manufacturing purposes. (iv) It draws attention to the value of the solids-not-fat content of milk. (v) It will make the producer more " mastitis conscious " because udder disease decreases the solids-not-fat content more noticeably than it does the fat content. (vi) It can easily be assessed—indeed it is normally measured for all producers sending in to creameries.

Bacteriological aspects. When we consider the yard-stick for bacteriological quality the subject is much more open and liable to individual opinions.

There is no universal agreement as to what constitutes " bacteriological quality " and to overcome this difficulty the term " hygienic quality " has been proposed, which includes several properties—bacterial numbers, keeping quality, mastitis, visible dirt, etc. (Table BG I, p. 64). In our opinion the ideal would be a measurement both of bacterial numbers *and* keeping quality, but this is impracticable. Of the two, keeping quality is the more important commercial quality and so should become our yard-stick. We have not yet solved our problem because keeping quality is an arbitrary quality—it all depends on how we define it. There is much to be said for a definition which simulates commercial practice, but this introduces local conditions and lack of uniformity. It is proposed, therefore, to define keeping quality as the time required for the milk to reach the clot-on-boiling condition when held at 18° C. from the time of arrival on the creamery platform.

Methods of Testing. *Chemical—Total solids.* There are two possible methods of measuring total solids in milk: (i) gravimetric; (ii) Gerber for fat and lactometer for gravity.

The second double-test method is much to be preferred for the purpose in view because: (*a*) the tests are already in use universally and well known; (*b*) the gravimetric method requires an accurate balance; (*c*) fat and solids-not-fat values are obtained separately and so give valuable information; (*d*) the methods are simple and easily taught.

Bacteriological—The Measurement of Keeping Quality. It should be clearly understood that the keeping quality test itself or the clot-on-boiling (C.O.B.) test is a direct measure of keeping quality, in fact, it is how we define it, whereas other tests such as the methylene blue and resazurin tests are *indirect* measures of keeping quality. It is therefore not fair to compare them from the point of view of accuracy without considering other aspects—quickness, convenience, cheapness, etc. Broadly speaking, the quicker the test the less accurate it is (Table PT II, p. 846).

We must also consider that most tests do not measure one component of hygienic quality (Table BG I, p. 64) only but often two and sometimes three. This is illustrated in Table Q XII from which it will be seen that the C.O.B. test (which, of course, really defines keeping quality) can also be used as a measure of bacterial numbers, although some bacteria do not produce acid or rennet and so have no influence on the C.O.B. test. The methylene blue test is a reasonably reliable measure of both keeping quality and bacteria, but resazurin over the range disc 6 down to 1 is influenced by animal cells and so reflects mastitis.

The plate count measures bacterial numbers accurately but is not very reliable as a measure of keeping quality. The sediment test measures visible dirt but is no index at all of keeping quality or bacteria.

TABLE Q XII

PROPERTIES MEASURED BY COMMON BACTERIOLOGICAL TESTS

	Time to reach C.O.B.	*Methylene blue* 37°	*Resazurin* 37° (1 *hr.*)	*Plate count* 37°	*Sediment*
Keeping quality . .	+ + +	+ +	+	+	—
Number of bacteria .	+	+ +	+ +	+ + +	—
Mastitis (cells) . .	—	—	+	—	—
Visible dirt . . .	—	—	—	—	+

The advantages and disadvantages of the common bacteriological tests are summarised in Table BG VII (p. 73). Since keeping quality is the property that the buyer is most interested in, it is obvious that if we can measure it by a simple technique, that will automatically be the best test from the buyer's point of view. The actual C.O.B. test is very simple—it merely involves placing 5 ml. of the sample in a pot of boiling water for 5 min. and observing if the milk clots. The chief difficulty in the keeping quality or C.O.B. test is arranging for tests to be made outside the ordinary laboratory hours of 8 or 9 a.m. to 5 or 6 p.m.

The working day of 8 or 9 hr. leaves an awkward gap of 15 or 16 hr. at night to be covered but this can be circumvented by taking advantage of the fact that refrigeration of milk samples holds the bacteria in a static or almost static condition. If there is any change in refrigeration (32° to 40° F.), the trend is for good milks to improve and for bad milks to deteriorate, so that refrigeration is sound, or at least, not a disadvantage from the technical point of view. In commercial practice bulk raw milk has to retain its keeping quality at about 40° F. for about 18 hr. If, therefore, any one producer's milk is graded down because of the overnight refrigeration, this fact enhances, not diminishes the value of the refrigeration part of the proposed testing procedure.

Table PT I (p. 845) illustrates the approximate equivalents of the clot-on-boiling and other bacteriological tests from the point of view of platform rejection standards.

Frequency of testing. All producers should preferably be tested every week. Sampling of producers' milks would be as under the former N.M.T.A.S. This would give 13 chemical results and 13 bacteriological results in every quarter.

The average *total solids* and average *bacteriological grading* would then be calculated at the end of each quarter:

$$\text{Average T.S.} = \frac{TS_1 + TS_2 + \text{etc.}}{13}$$

$$\text{Average bacteriological grading} = \frac{G_1 + G_2 + \text{etc.}}{13}$$

The procedures developed by the former N.M.T.A.S., and now used by the J.M.Q.C.C. (p. 754), could easily be adapted for this scheme.

Methods of Calculating Payment. Having obtained an average grading for the quarter we have to decide how to apply this information to decide the price to be paid to the producer. There are fundamentally two methods: (i) discrete increments; (ii) infinitely variable adjustments. Although the method of discrete increments has the advantage of simplicity, there are two important advantages of infinitely variable adjustments: (i) an intelligent producer could soon learn to keep his chemical composition at the lower end of one grade. (ii) The smallest improvement would be reflected in an increased price and this would have an important psychological effect on the producer. Otherwise effort to obtain improvement *inside any one grade* would not be rewarded.

By the use of a nomograph (Davis, 1945, *DI*, **10**, 27) the smallest improvement or deterioration would be reflected in a change of price. The "reading-off" of the price for the quarter is a matter of seconds.

This scheme would award a price which varied *directly* according to the total solids content of the milk and varied by an arbitrarily decided amount according to keeping quality.

Method of Awarding Price Differentiation. A number of methods might be suggested for this. One method would be to pay the standard average price for the 3 months of the quarter. The producers' grading score would be known within the next month and the adjustment could then be made at the end of this fourth month. For example, suppose a producer of 20 gal. a day had scored a price equal to 2d. in excess of the average for the quarter, then he would receive, say 91 × 20 × 2d. = £15 approx. quality payment.

A score of equivalent to 2d. *below* the average would mean that a deduction would be made.

A proposal for initiating the scheme. Once any scheme such as that outlined had been agreed upon, it would be essential to give all producers a chance of seeing how the scheme would operate before any financial adjustment were made. One method would be to inaugurate the scheme in its entirety as far as the testing, calculation, and notification of results were concerned, but not to make any actual change in prices for a period. Such a trial period could run from April to Sept., the producer being notified in July and October what price he would have received *if* the quality payment scheme were actually in operation.

Differential payments would then start from October onwards, *i.e.* he would receive a first quality payment adjustment in January. Since the period from October to March is an easy one from the keeping quality point of view, the producer would then have in effect a whole year before he would suffer any appreciable penalty for poor keeping quality. Alternatively, the trial period could run for a whole year.

The control of financial balance. At the start of the scheme it would be easy to adjust the balance of payment, since average quality would receive the existing pool price. In effect, the producers below average would subsidise those above average. This principle could be applied indefinitely no matter how the average total solids and average keeping quality rose as the result of quality payment. This is, in effect, how the present premiums for T.T., etc. milk are financed.

Existing premiums for T.T. producers and levies or premiums for producer-retailers would not be affected by the proposed scheme.

The general conclusions on the problem may be summarised as follows:

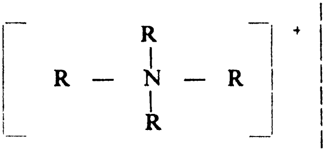
Any quality payment scheme is bound to be criticised on many aspects and this scheme is put forward to form a basis for discussion. The essential basis of the scheme can be summarised as follows: (i) Quality payment is the logical and perhaps the only solution to the problem of the unsatisfactory producer. (ii) Milk should be bought on a total solids, not a gallonage, basis, and on keeping quality. (iii) The buyer need not have any financial interest in the results of the grading tests. (iv) Machinery for the implementation of a quality payment scheme already exists in this country. (v) The magnitude of the required differential payments and the procedure for calculation can be adjusted in the light of experience. (vi) Before actual differential payments are made a trial period should be arranged. *See* Bacteriological grading; Milk marketing; Nutritive value.

Refs.: Min. Agric. (1953), Rep. Working Party, H.M.S.O.; Wheldon (1948), *JSDT*, **1**, 78; Davis, 81; Davis (1952), *A*, **77**, 499; Boekel (1949), *IDC*, **1**, 344; Davis (1951), *DF*, Aug. and Sept.

QUARG. *See* Cheese, p. 199.

QUATERNARY AMMONIUM COMPOUNDS. Quarternary ammonium germicides have received considerable attention in the past 10 years in relation to their use as sterilising compounds.

Chemically, these substances belong to the general class of compound in which the nitrogen atom has 4 organic co-valences and 1 electro-valency. The general formula of this class is given below:



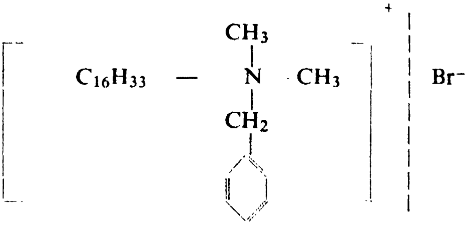
$$\left[R - \underset{\displaystyle R}{\overset{\displaystyle R}{N}} - R \right]^{+} X^{-}$$

X being the anion attached by the electro-valency. R being organic radicles.

Any basic nitrogen atom can, by treatment with the proper radicles, be converted into a quaternary ammonium compound. Thousands of examples may be found in the chemical literature in all branches; many have physiological importance, for example, in the alkaloids, but the germicidal quaternary ammonium compounds may be regarded in a class by themselves. These substances are surface active, and exhibit physico-chemical properties similar to other surface-active materials, such as soaps and anionic wetting agents.

The surface-active germicidal quaternary ammonium compounds are cationic, and consist of one or more hydrophobic carbon chains which may or may not contain other groupings, while subsidiary or non-surface-active promoting groups make up the balance of the co-valencies. The anion which is attached by an electro-valency may be almost any type of acid radicle, the resultant compound thus being a salt. The anion is very often found to be bromide, chloride, sulphate and occasionally metho-sulphate. Iodides and organic radicles are occasionally used, but they are uncommon.

A typical formula of surface-active quaternary ammonium compound is given below:



Owing to their surface-active nature, solutions of these compounds in water show considerable reductions of surface and interfacial tensions, good wetting and spreading powers and, to a greater or less degree, the ability to make stable foams. In the latter case the configuration of the molecule plays an important part. The salts can be converted into the hydroxides by treatment either with moist silver oxide, or more commonly by adding alcoholic caustic potash to an alcoholic solution of the quaternary salt and filtering off the inorganic potassium salt thus obtained, leaving the quaternary hydroxide in the alcohol from which it can be recovered by removing the solvent by distillation.

Chemically, this class of compound is very stable, and often a decomposition can be effected only by the most drastic treatment. However, they undergo double decomposition reactions with surface active anionic materials quite easily. The resulting anionic-cationic complex which is formed often appears as an insoluble precipitate or oily suspension, this action being dependent upon the particular compounds used in the experiment.

Precipitates can also be obtained with many inorganic salts in which the salt is formed by the union of a strong alkali with a weak acid, sodium metasilicate being an instance of this. The degree to which complexes of this kind will be formed depends upon the particular quaternary used, and experiments show that it is not always safe to predict the degree of precipitation which may occur, particularly when other ions are present in the solutions.

There has been too great a tendency to generalise about these compounds as a class, leading to statements which, while holding good for one particular quaternary, may be entirely false when applied to another member of the class.

Generally, the surface active quaternary ammonium compounds are compatible with substances such as sodium carbonate, and even with trisodium phosphate, but caution must be observed even in making this statement, because the actual solubility of the compound is also a factor when making solutions of them with other salts.

The number of carbon atoms found in the surface-active chains in these substances varies from 10 or 12 to 20 or sometimes 24. Much depends upon whether the compound prepared is a single chain or a twin chain compound; with the latter, a larger number of carbon atoms can be used in the total surface-active chains than in the former before insolubility is reached.

It may be said that the work of Domagk (1935) was the first important publication to draw attention to the possibilities of this class of compound as a germicide, and the medical field was the first one to receive attention.

Interest in the use of these substances for sterilising food plant and equipment was first observed in the United States, where a considerable literature has grown up in the past few years.

At first, disinfectant preparations manufactured with these compounds were assessed for their germicidal activity by the F.D.A. phenol coefficient method. Many preparations showed extraordinarily high phenol coefficients, and this led to an examination of the properties of these compounds so far as their anti-bacterial activity was concerned. As a result, the use of the phenol coefficient was severely criticised by Klarmann and Wright (1946) and other workers.

The main points raised were, firstly, that in the F.D.A. method, carry-over of the compound after exposure resulted in a bacteriostatic effect in the culture medium which prevented the growth of viable organisms. A second point was that surface-active cationic materials caused the clumping of cells on the walls of the medication tube, so that when a sample was withdrawn for culturing, this did not include considerable numbers of viable organisms which were present in the clumps. Other secondary objections were also raised, and the result of this work was to promote investigations into more satisfactory methods of evaluating these germicides.

DuBois (1947) dealt with the objection raised on the question of clumping, and representative testing methods which overcome most, if not all, of the objections raised may be found in papers by Mueller, Seeley and Larkin (1947), Davies (1949), Pressman and Rhodes (1946), James (1947), and Resuggan (1951).

The use of special inactivating materials in order to remove the possibility of bacteriostasis, has also been reported by the following workers: Baker, Harrison and Miller (1941), Quisno, Gibby and Foter (1946), Weber and Black (1947), and Klarmann and Wright (1948).

The actual killing powers of the quaternary ammonium germicides cover a wide range, depending upon the type of compound and the type of organism against which it is being tested. While some examples have been noted where destruction of 100 per cent. of the organisms takes place in a few minutes at a dilution of 1 in 20,000, others where dilutions of 1 part in 200 have not given a 100 per cent. kill are also known.

Micro-organisms exhibit considerable differences in their resistance to these compounds, and speaking generally, it may be said that Gram-positive types succumb far more readily than Gram-negative, while yeasts are, in the main, more resistant still, and moulds even more so. This is a sweeping and somewhat dangerous generalisation, but every compound shows differences in its activity against different organisms. The most satisfactory are those which show a more even rate of activity against all the main groups, and it must be emphasized that generalisations about anti-bacterial power arising from only one or a few test compounds can be very misleading.

If it is proposed to use one of these compounds as a sterilising medium in any field, it is advised that, firstly, data concerning the activity of the compound against the type of flora to be found in that field be investigated, and better still, tests at various dilutions under practical conditions be made before any conclusions are finally reached. It must be borne in mind that the mixed flora encountered in practice presents a different problem from a single type of test organism against which the compound may be tested in the laboratory, and under practical conditions, strikingly different results may be obtained. The most satisfactory compound will be the one which gives a 100 per cent. kill in the shortest space of time at the lowest concentration against such a mixed flora. An example of this method of testing has been given by Bishop, Ward and Kloss (1951).

At the lower concentration, and very often this may be as low as 1 part in 5000 of water, a considerable bacteriostatic effect may be found for this class of compound, and although this property can lead to confusion in evaluating actual killing power, it is in practice extremely useful.

In the food industries the problem of the survival of a few hundred organisms per sq. ft. may not in itself appear to be serious, but after some hours or days when the surface is in contact with foodstuffs, the bacterial population arising from the initial few hundred may be colossal, and may be a danger, not only to the keeping quality of the product, but to health. Therefore, the bacteriostatic effect which prevents these few hundred organisms from growing, may be considered to be quite important.

Turning to the problem of the mode of action of these substances, a good deal of work has now been carried out. It seems that, at bacteriostatic dilutions, there is an adsorption of the surface-active molecule or ion on to the bacterial cell which may interfere with the vital processes, and thus bring about inhibition of growth. At the higher concentrations, those which in effect produce a definite destruction of the micro-organisms, the adsorption is sufficiently heavy to bring about lysis of parts of the cell wall, permitting the escape of the bacterial protoplasm into the surrounding medium. The speed and extent to which this process extends will depend essentially upon the concentration of the disinfectant.

QUATERNARY AMMONIUM COMPOUNDS

The work of Salton, Horne and Cosslett (1951), showing the effect of cetyltrimethylammonium bromide, enables this process to be demonstrated by means of electron micrographs, a study of which is extremely illuminating and places beyond doubt the mode of action of the quaternary ammonium germicides.

Previous reference has been made to their physico-chemical properties, and in this connection it should be stated that the surface-active cations adsorb quite strongly to most surfaces, and this is, of course, an important primary condition for their anti-bacterial activity.

It is interesting to observe that the concentration required to kill 50 per cent. of test animals in acute toxicitv trials, usually works out at about 500 mg. per kg. bodyweight of the test animals, and several quaternary ammonium compounds seem to exhibit the same acute toxicity. This refers to oral dosage.

On the question of chronic toxicity, there is no evidence that minute traces which may be left in vessels to come in contact with foodstuffs, can have the slightest effect upon the human organism, and while an attempt is made in some quarters to cast doubts upon these compounds on this particular gro und, it can be pointed out that similar objections can be raised against a large number of substances which have been in everyday use in the food industries for many years. It should also be pointed out that the acute toxicity demonstrated at the level above mentioned, really results from a high concentration of surface-active

COMMERCIALLY PRODUCED SURFACE-ACTIVE QUATERNARY AMMONIUM GERMICIDES

Produced in Great Britain (List may not be complete)

Chemical name of quaternary ammonium germicide	*Manufacturer*	*Trade name (where known)*
Di-*n*-decyldimethylammonium bromide	The British Hydrological Corporation	Deciquam
Di-*n*-octyldimethylammonium bromide	The British Hydrological Corporation	Diometam
Cetyltrimethylammonium bromide	Imperial Chemical Industries, Ltd.	Various preparations sold as: Cetavlon, Cirrosol O.D., Vantoc A., Lissolamine A.
Tetradecylpyridinium bromide	Imperial Chemical Industries, Ltd.	Fixanol V.R. Vantoc B.
Cetyl pyridinium bromide	Imperial Chemical Industries, Ltd.	Fixanol C.
Lauryl pyridinium chloride Cetyl pyridinium chloride Lauryldimethylbenzylammonium chloride Cetyldimethylbenzylammonium chloride Mixed alkyldimethylbenzylammonium chloride Stearyldimethylbenzylammonium chloride	Leda Chemical Co. Ltd.	

material in the stomach, but the destruction of the membranes is primarily due to physico-chemical action on the mucous membrane of the stomach.

It seems clear that the properties of lack of corrosion, stability, general harmlessness, absence of pronounced tastes or flavours, render this class of germicide of the greatest use in all branches of the food industries, and there can be little doubt that, in spite of official reluctance to admit any new chemical agent, they will continue to make progress in the future as they have done in the past few years.

A number of methods of determining the concentration of a quaternary ammonium germicide in solution have been developed. The method of Auerbach (1944) and a useful variation developed by Epton (1948), are probably most frequently used. These methods rely upon the effect of surface-active cations on the colour of certain dyestuffs such as bromphenol blue, and variations in the manner by which such colours are utilised, make the essential differences between several methods published.

There are also argentimetric methods, but these suffer from the disadvantage that not only the halide anion of the quaternary preparation, but also any alkali halides present will be determined.

A review by DuBois (1946) surveys numerous methods of determination, and once again it is necessary to emphasize that a method which is found to be highly satisfactory for one quaternary ammonium compound, may not be as good for another of different chemical constitution, so that it is important to carry out a sufficient number of preliminary tests in order to determine the best method for the particular compound involved.

A number of these quaternary ammonium compounds are produced in Great Britain and, while the list given on the opposite page may not necessarily be complete, it gives a list of these products with their trade names, where known, and the manufacturers.

See Bottle washing; Cleaning and sterilising; Detergents; Disinfectants; Legal aspects.

Refs.: Auerbach (1944), *IEC*, (AE), **16,** 739; Baker *et al.* (1941), *JEM*, **74,** 621; Bishop *et al.* (1951), *J. Inst. Brew.* **57,** 110; Davies (1949), *JH*, **47,** 271; Domagh (1935), *Deutsch. Med. Wochschr.*, **61,** 829; Dubois (1946), *Soap San. Chem.*, **22,** (11); Dubois (1947), *Soap San. Chem.*, **23,** (5), 139; Epton (1948), *TFS*, **44** (4); 226; James (1947), *Soap San. Chem.*, **23,** (11), 125; Klarmann and Wright (1946), *Soap San. Chem.*, **22,** (1), 125; Klarmann and Wright (1948), *Am. J. Pharm.*, **120,** 146; Mueller *et al.* (1947), *Soap San. Chem.*, **23,** (9), 123; Pressman and Rhodes (1946), *Soap San. Chem.*, **22,** (4), 137; Quisno *et al.* (1946), *Am. J. Pharm.*, **118,** 320; Rahn and Eseltine (1947), *Ann. Rev. Microbiol.*, p. 173; Salton *et al.* (1951), *JGM*, **5,** 405; Weber and Black (1947), *Soc. Am. Bact., Abstr. Proc.*, 47, Gen. Meet. p. 44.

QUINHYDRONE ELECTRODE. This electrode depends on the fact that a noble or inert metal immersed in a solution of quinhydrone gives a fixed potential (really an E_h or oxidation-reduction potential) which is influenced only by the acidity or *p*H of the solution. It is therefore used as an *indirect measure* of the *p*H of any substance with which it is mixed. The advantages of this electrode in dairying lie in the facts that it is very simple to use, is almost fool-proof and can be used with semi-solid " mushes ", *e.g.* cheese.

The following recommendations are made by Moir (*A* (1931), **56,** 445):

> The electrode may be of bright platinum, since it is always in contact with the same solution, and is not so liable to " poisoning "; but if difficulties are encountered a gold one may be found better. The electrodes for use in the solution to be tested are preferably made of gold foil (about 1·0 × 0·5 × 0·025 cm.), to which gold wire (S.W. Gauge 21) is attached, first by hammering, and then by heating just to redness. By the same method the gold wire is then attached to a platinum wire to be fused into a glass tube. Some workers use gold-plated platinum electrodes on account of the risk of melting the gold during flaming, but this gold plating requires renewing from time to

time. All gold electrodes can be flamed without difficulty, provided this is done at a distance from the bright light of a window, so that care can be taken not to heat beyond the first sign of redness. The flaming must be done with an alcohol lamp, to avoid the risk of " poisoning " by coal-gas impurities.

The frequent flaming may cause cracks to develop in the tube into which the platinum wire is fused. Care should be taken to obtain suitable glass tubing for this purpose, in order to avoid loss of time due to frequent cracking ; in fact, the process of fusing the platinum properly into tubes, simple as it appears, may very well be delegated to an expert. Abnormal potentials are sometimes caused by leakage of liquid through cracks, which I have found to be most readily detected by keeping the electrodes, when not in use, in a test-tube with strong nitric acid. This gradually passes through the crack and attacks the mercury within, producing a white salt. The mercury used to put in these tubes ought to be clean, pure, and dry, and is best kept in a bottle fitted with dropping-tube and rubber teat, so that small quantities can be transferred without loss.

If by accident an electrode becomes amalgamated, the mercury can be removed by flaming, but on occasion blackish deposits remain—probably due to copper which may have reached the mercury from a connecting wire. These deposits can be removed by plunging the electrode while almost red hot into strong nitric acid. Scrubbing with a clean brush and soap and water has been recommended for removing sticky material from the electrodes prior to flaming. Another method is to place the electrode in a tube with nitric or chromic acid in a boiling water bath, and sometimes it may be necessary to use all these methods repeatedly. In other cases, failure to give correct results is due to the mercury in the tube becoming moist (especially with acid fumes), whereby a small mercury-copper cell results and causes an abnormal potential.

Connection between the material and the other half cell is made by means of an agar bridge, which is prepared by adding 5 g. of agar-agar to 100 ml. of 3·5 *N* potassium chloride solution, and heating in a large test-tube (or beaker) immersed in boiling water. Several U-tubes of suitable size are prepared, clean and dry. To one end of each is fitted a piece of rubber tubing and clip, so that it can be filled by suction, and the clip applied when full. The other end must be left in the test-tube until the whole mass is quite solid, when it may be removed, and after detaching the rubber tube, it should be kept until required with both ends in test-tubes of saturated potassium chloride solution. Before using, the end which is to go in the solution to be tested should be left over for 10 min. in distilled water and rinsed clean. This is of importance, because very small quantities of potassium chloride are able to cause considerable reductions in the *p*H value. The advantages of an agar bridge is that it minimises the risk of potassium chloride reaching the solution to be tested.

The difficulties associated with the preparation of a standard calomel electrode for reference purposes can be avoided by the use of a solution containing potassium chloride (0·09 *N*) and hydrochloric acid (0·01 *N*) in the presence of dissolved quinhydrone. It is preferable to renew it daily. The vessel should be rinsed once or twice with small quantities of this solution, which are blown out through the U-tube. It is then filled about half full, and a small amount of quinhydrone added (0·1 g. is usually sufficient). After replacing the cork, the U-tube is filled by blowing gently, and the clip at once closed. Air bubbles above the capillary greatly reduce the sensitiveness of the apparatus. If he cork fits well, little or no leakage should take place from the capillary. Immediately after disconnecting, the clip should be opened slightly, and a few drops allowed to run out of the capillary, so that any strong potassium chloride solution which may have diffused in will not be allowed to flow back into the apparatus. This precaution is essential if the reference electrode is to be maintained correct for more than one day

One electrode is sufficient, but Lester's plan of having three in the solution to be tested was adopted. Thus, when one became " poisoned " it was at once observed because it gave a different reading from the others. " Poisoning " did not often occur when dealing with clear solutions but liquids like milk, especially after the protein had been coagulated, gave more trouble. In such cases, washing the electrodes, first under the tap, and then with distilled water, did not suffice, but, in addition, flaming was often necessary after each determination. In order to obtain good results in solutions or mixtures containing clotted material, it may be necessary to use a larger vessel and to stir liquid mechanically.

Every day before measuring an unknown *p*H a solution of known *p*H should always be tested. For this purpose, 0·05 *N* potassium phthalate, which has a *p*H of 3·97 is convenient.[1] " Standard acetate " mixture, which is 0·1 *N* with respect to both acetic acid and sodium acetate, and which has a *p*H of 4·626, is easily made up from standard acid and sodium hydroxide solutions of about half-normal strength. A few ml. of the solution to be investigated are placed in the boiling tube, the agar bridge inserted, and about 0·1 g. of quinhydrone added with a spatula. The electrodes are at once inserted and used to stir the mixture briskly, and the potentiometer reading taken as soon as possible (because of the fact that a drift takes place after a time in certain solutions). When the value obtained for a solution of known *p*H differs by more than a millivolt from what is expected, an investigation and cleaning of the apparatus and solution should be carried out. The formula for calculating the *p*H when using the reference (HCl-KCl) electrode described above is :

$$p\text{H} = -2{\cdot}03 + \frac{\text{E}}{0{\cdot}0577 + 0{\cdot}002\,(t - 18)},$$

where E is the voltage (in volts) and t° C. is the temperature. By drawing a graph of *p*H against E.M.F. at 18° C. the *p*H values can be read off at a glance. Lines can be drawn to obtain the values at adjacent temperatures.

The statement is generally made that the availability of the quinhydrone electrode is confined to the acid side, but Biilmann has compared it with the hydrogen electrode, and obtained results agreeing well, even at *p*H values above 7·0. In most solutions it is satisfactory up to *p*H 9·0, provided that the potentiometer readings are taken promptly after adding the quinhydrone.

Apparatus. A simple, inexpensive quinhydrone cell for rapid work has been described (*A* (1931), **56,** 449). This was devised for determining the *p*H of a large number of samples or liquid or solid substances without the aid of salt-agar bridges or glass taps.

The half cell consists of a Pyrex tube, about ½ in. in diameter, which has been drawn out into a jet and bent over. It is important that the jet be about ¾ to 1 in. above the bottom of the tube. To prepare the standard quinhydrone half cell, pour some hydrochloric acid potassium chloride reagent (9 parts of 0·1 *N* KCl and 1 part of 0·1 *N* HCl very accurately standardised) into the cell, add about 0·05 g. of quinhydrone, shake, allow to settle, and then gently blow over. No bubbles should be allowed in any part of the cell. The amount of liquid put in should be so gauged than when blown over, the level is about ¼ in. above the jet, thus preventing siphonage. For *p*H determinations of liquids a similar cell is prepared, except that the liquid under test is used instead of the hydrochloric acid-potassium chloride solution.

Gold electrodes, after having been rinsed in distilled water and flamed to a dull red heat (momentarily) in a pure alcohol flame, are immersed in the cells, the jets of which are dipped into saturated potassium chloride solution just before a reading is taken and removed immediately afterwards.

Sensitivity is good, and a constant value should be obtained in 1 to 2 min. from the time of mixing-in in the quinhydrone.

A solid material may be ground in a mortar with quinhydrone, pressed into a short piece of tubing (a 1 in. section of a test-tube ½ in. in diameter), and the electrode inserted in this " mush " which is then allowed to dip into saturated KCl and contact made as before.

The cells may be emptied by jerking the liquid out and then blowing back *through* the jet.

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[1] The phthalate buffer is now considered to have a pH value of 4·00 on the B.S. scale. *See* p. 511.

R

RABBIT MILK. *See* Mammals.

RABBITO TAINT IN BUTTER. A characteristic bacterial taint. *See* Butter; Putrid butter; Stability.

RACEMISED CASEIN. Casein as a naturally occurring organic compound is optically active (p. 166) but solutions in dilute alkaline solution gradually lose their activity until a final low constant value is obtained. It is probable that a slow proteolysis actually occurs as ammonia is evolved and proteoses, etc., appear in the solution. The racemic " casein " is not attacked by proteolytic enzymes or digested by animals or, apparently, attacked by bacteria.

Refs.: Dakin and Dudley (1913), *JBC*, **15**, 263, 271 ; Dakin (1912-13), *JBC* **13**, 357 ; Davies ; Rogers.

RADIO-FREQUENCY HEATING. *See* Pasteurisation, alternatives to.

RANCIDITY. This term is used in two senses : (i) in a general sense to describe any off-taint in fat ; (ii) in more precise chemical senses to describe certain chemical changes in fat such as (*a*) hydrolytic changes, *e.g.* liberation of free fatty acids such as butyric ; (*b*) oxidative changes, *e.g.* peroxide formation ; (*c*) liberation of trimethylamine from lecithin ; (*d*) formation of ketones by mould action. The term *rancidity* in the chemical sense is best limited to (*a*) above, (*b*) being described as *tallowiness*, *cardboard flavour*, *oiliness*, etc., (*c*) as *fishiness*, and (*d*) as *ketonic rancidity*. In practice it is impossible to dissociate them and the chemical reactions involved are complex and interlinked. The fact that the pure substances, *e.g.* butyric acid, are of relatively mild odour, is a further complication. By definition above, true rancidity is the liberation of fatty acids, especially the lower ones, by *lipase* action. The lipase may be present in the original milk or produced by micro-organisms. Heat-treatment will destroy or minimise both, so that rancidity indicates lack of, or inadequate, heat-treatment, and/or contamination in handling, manufacture, or packing the product. *See* Auto-oxidation ; Butter; Enzymes; Fats; Fishiness; Flavours.

Refs.: Lea (1938), *Rancidity in Edible Fats*, H.M.S.O. ; Davies ; Richmond; Costilow and Speck (1951), *JDS*, **34**, 1119 (rancid milk and bacteria) ; Dunkley and Smith (1951), *JDS*, **34**, 935, 940 ; Dunkley (1951), *JDS*, **34**, 515 ; Fredeen *et al.* (1951), *JDS*, **34**, 521.

RANDOM. The term " random " is often used when discussing analytical results on dairy products, and in planning research schemes. It is surprising how easy it is for some subconscious influence to affect the selection of so-called random samples or results. The only really safe method is to take the required number by a pre-arranged order, *e.g.* 5th, 10th, 15th, etc., or by a statistically devised method. *See* Statistical formulae.

RANGE. It is frequently required to interpret a property in terms of a laboratory test, *e.g.* keeping quality in terms of the methylene blue or 10 min. resazurin test at 37° C. It may be quite misleading to quote a mean equivalent value unless the range is also given. Thus in Table PT I, p. 845, the *mean* keeping quality of 21 milk samples giving a disc reading of 3 or 3½ on the 10 min. resazurin test is 10·6 hr., but the *range* varied from 3·5 to 16. Due attention to the range of results must always be given when assessing the value of any test or of any result. The most convenient and useful statistical aspect is the *co-efficient of variation*. *See* Statistical formulae.

RAOULT CORRECTION. This is a correction which may be applied in the freezing-point test for added water (p. 485) for the super cooling of the milk.

RAPID ABNORMALITY INDICATOR. This is a simple electrical apparatus for the rapid detection of abnormal (mastitis) milk. There are three types of test made for this abnormality : (i) the clinical test commonly made by veterinary surgeons in the course of their farm work ; (ii) the indirect tests for physiological or chemical abnormality in the milk ; (iii) bacteriological examination of aseptically-taken single quarter samples. There is no quantitative criterion for mastitis. At one extreme we have the view that the finding of one colony of *Str. agalactiae* on a plate constitutes a case of the disease, and at the other the view that only when a veterinary surgeon has pronounced an animal positive as the result of a clinical examination can it be said to have mastitis.

Numerous attempts to bridge the gap have resulted in the so-called " indirect tests ". These may be classified as under :

(*a*) Tests for increased cell (leucocyte) content : (i) centrifugal deposit test ; (ii) catalase test ; (iii) resazurin test ; (iv) cell count.

(*b*) Tests for chemical abnormality in the milk : (v) rennet test ; (vi) chloride test ** (either by a quick silver method or a conductivity measurement) ; (vii) brom-cresol purple paper test **

Of these, only those marked ** can be regarded as " instantaneous tests ", taking a few seconds to perform, and of these two the chloride has important advantages over the brom-cresol purple test : (i) it is quantitative and objective ; (ii) it detects more cases of abnormal milk ; (iii) it is unaffected by slight souring.

The fact that the condition of a cow's udder known as " mastitis " usually causes an increase in the chloride content of the milk has been very well known for a number of years, and this chloride increase has been measured chemically and the results used diagnostically (Tables RA I and RA II).

TABLE RA I

Conductivity × 10^{-4} *mhos*	*Chloride content %*	
	Davis (18° *C.*)	*Davies* (20° *C.*)
40	0·075	0·073
50	0·125	0·127
60	0·175	0·185
70	0·225	0·220 (?)
80	0·275	
90	0·325	
100	0·375	

TABLE RA II

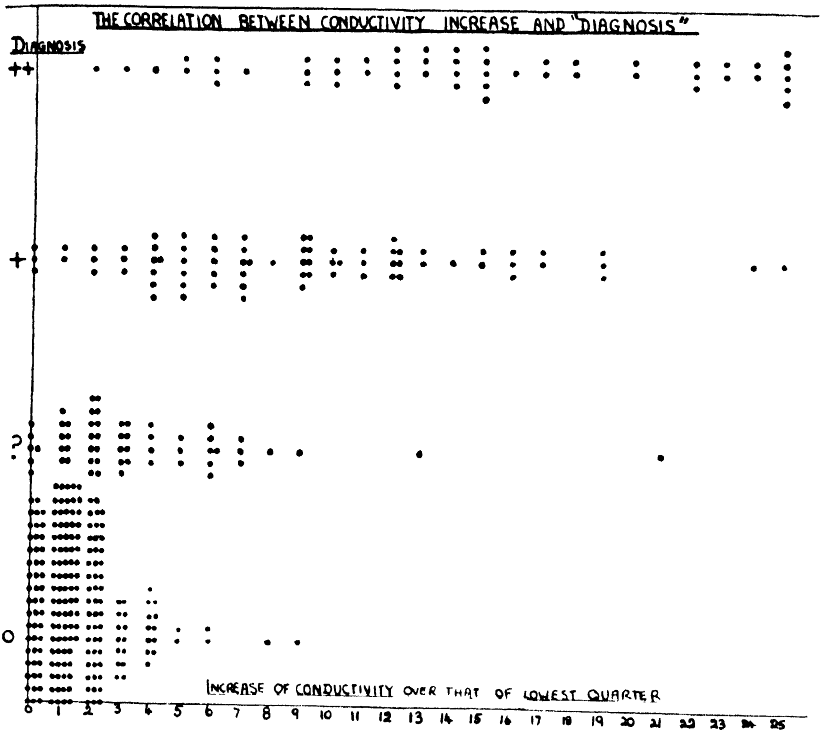
RANGES FOR NORMAL MILKS

	Conductivities as × 10^{-4} *mhos*	*Chloride %*
Koeppe (1898) . . .	45 to 48	0·100 to 0·115
Plucker and Steinruck (1930) .	39 to 56	0·070 to 0·155
Damhofer and Moser (1930) .	Up to 54	Up to 0·145
Davies (1936) . . .	35 to 53	0·050 to 0·140
Malcolm (1942) . . .	Up to 49	Up to 0·120
Davis (1944)	Below 46 (normal)	Below 0·105
	46 to 50 (abnormal or late lactation)	0·105 to 0·125
	Over 50 (abnormal)	Over 0·125

RAPID ABNORMALITY INDICATOR

With all the indirect tests, factors such as stage of lactation, age of cow, breed, feeding, etc., can affect the biochemical properties of the milk. Mastitis in one quarter results in a chemical change in the milk from that quarter, so that the tests only become reasonably accurate when considered in relation to differences between quarters.

If only the bacteriological findings are considered in assessing the value of the test the agreement is not too good, but if all the results of a number of different tests are considered and a " diagnosis " made on abnormal bacteriological, chemical and physiological findings, then the agreement is good, bearing in mind the nature of the test and the inevitable biological variation (Fig. RA 1).



"Diagnosis" is based on the following tests: Streptococci, Staphylococci, other bacteria, cells, catalase, resazurin, rennet, visual appearance. O = no abnormality, ? = doubtful + = definite ++ = gross abnormality

Increases in conductivity are based on differences above lowest quarter value for each cow tested. If all four were above 50×10^{-4} mhos, 50 was taken as the basic value.

FIG. RA 1.—*The Correlation between Conductivity Increase and " Diagnosis "*.

It may therefore be reasoned that the best routine method of detecting abnormal quarters is to compare the chloride contents of the milk of the four quarters of each cow.

The battery-operated instrument (Fig. RA 2) for use in the cowshed consists of: (*a*) control unit containing batteries; (*b*) electrode handle incorporating the milking-cup and carrying an indicating meter calibrated in chloride percentages and conductivity units. A device is fitted which obviates the necessity of washing the instrument between samples. The handle is joined to the battery unit by 6 ft. of light-weight cable.

After rejecting two streams the quarter is milked into the electrode handle (Fig. RA 3). The self-cleaning device is then operated and the conductivity read off directly on the meter scale (Fig. RA 4). The sample is then ejected and the operation repeated on the next quarter.

No temperature compensation is included as the samples are taken and tested at body heat.

The results may be interpreted as in Table RA III.

TABLE RA III

Increase over lowest value[1] *for any quarter in one cow*	*Abnormality*	*Interpretation*
0, 1, or 2	Nil or negligible .	Highly probable that no infection present
3 or 4	Slight . . .	Quarter may be clean or lightly infected; only rarely badly infected
5 to 15	Definite . .	Quarter certainly infected
Over 15	Gross . . .	Quarter badly infected

[1] In 10^{-4} mho units.

Summing up, therefore, a difference of 1 or 2 may be ignored for practical purposes. A difference of 3 or 4 may be regarded as doubtful, and a difference of 5 or more indicates a definite abnormality, which is probably due to mastitis as there is a good correlation between differences in conductivity, and infection by *Str. agalactiae* and other known mastitis-causing organisms.

Table RA IV gives examples of tests on single quarter samples.

Refs.: Jones (1949), *SAB*, No. 1, 29.

RAPID RESAZURIN TEST. *See* Platform tests; Resazurin tests.

RATIONING OF MILK AND FOODS. *See* Milk marketing; Utilisation.

Ref.: League of Nations (1944), *Food Rationing and Supply*, Geneva.

RAW MILK, DETECTION IN PASTEURISED MILK. The phosphatase test will detect the presence of 0·1 to 0·2 per cent. raw milk in pasteurised milk. If pasteurised milk is filled into a can that has contained raw milk and not been washed, the phosphatase result is usually 3 to 4 L.B.U.

RECEPTION. A comprehensive term for the whole process of receiving, checking, testing, recording, tipping and pumping away of raw milk at a depot. A typical layout is shown in Fig. MPD 6, facing p. 652. *See* Management of creameries; Mechanical handling; Platform testing.

RECKNAGEL PHENOMENON. When milk is allowed to stand for several hours after milking, the specific gravity rises rapidly at first, due to the escape of entrained carbon dioxide bubbles, and then slowly until a final equilibrium value is obtained. The slow later change is called the " Recknagel effect or phenomenon " and was at first considered to be due to change in the protein. It is now considered that the change is due to the slow solidification of the fat. The average change is 0·001 in specific gravity or 1 degree of gravity. The importance

TABLE RA IV

STUDIES ON BACTERIOLOGICAL AND BIOCHEMICAL ABNORMALITIES IN SINGLE QUARTER MILK SAMPLES

(Davis, Newland and Wilby)

Cow	*No. of calves*	*Mths. in lactation*	*Daily yield*	*Strip cup*	*Streps*	*Staphs*	*Other bacteria*	*Catalase (cm.)*	*B.C.P.*	*Con-ductivity*	*Cell count (millions)*	*Resazurin (1 hr.)*	*Rennet (hr.)*	*Diagnosis*
30 B	10	6	30	—	0	7	0	2	—	38	0·40	5	1	0
				—	0	27	0	2	—	38	0·29	5	1	0
				—	0	0	0	1·5	—	38	0·23	5	1	0
				—	0	20	0	2·5	—	40	0·38	5	1¼	0
35 C	4	4	25	—	0	1380	0	3	?	38	0·28	5	1	?
				—	0	1120	0	6	—	40	1·68	4	1¼	+
				—	0	67	48	2·5	—	38	0·72	5	¾	—
				—	0	50	50	1·5	—	38	0·13	5	¾	—
4 D	2	3	25	—	0	750	0	6·5	—	42	1·45	3½	1	+
				—	0	30	0	5·5	—	41	0·57	4½	1	0
				—	0	178	0	7	?	47	2·13	3	>2	+
				—	0	600	0	5·5	—	42	0·63	4½	1	?
L.R.H.	1	2	15	—	3600	0	0	8·5	++	56	0·45	4½	>2	++
				—	0	0	50	2	—	41	0·09	5	½	0
				—	6000	0	0	6	+	46	0·96	4½	¾	++
				—	0	0	3500	3	?	41	0·33	4½	½	0
6 F	6	8	10	—	0	0	350	3·2	?	45	0·45	4½	1	0
				—	17,000	0	0	7·9	+	54	9·6	0	>2	++
				+	120,000	0	0	6·0	+++	77	>60	0	>2	++
				+	>120,000	0	0	7·6	+++	81	>60	0	>2	++
11	3	8	8½	+	0	100	0	6·7	++	61	1·56	5	>2	+
				—	0	5	0	5·1	—	49	0·27	5	1	0
				—	0	0	10	7·2	++	62	2·16	5	>2	+
				—	0	0	40	6·4	++	80	4·11	5	2	+

of this in the lactometer test will be realised when the equivalent difference in solids-not-fat 0·25 per cent. is considered. Milks vary in the magnitude of the effect. It is probable that the solidification of fat is the main cause but loss of gases and other changes may also play a part. *See* Density ; Richmond formula ; Solids-not-fat ; Total solids.

RECONSTITUTED CREAM, ARTIFICIAL CREAM. Cream which is made by the re-emulsification of butter in milk with the aid of certain emulsifying agents such as glyceryl monostearate, etc.

Cream which is prepared from hardened vegetable or animal oils is termed *synthetic cream* (p. 1005).

RECONSTITUTED MILK. This term normally refers to milk prepared by dispersing milk powder (*q.v.*) in water. (*See* also Infant feeding and Solubility). During the war the occasional incidence of sweet curdling (*q.v.*) led the public to believe that milk powder was being reconstituted to serve as liquid milk, but this was not so as without adequate safeguards food poisoning could result. For the detection of reconstituted milk *see* Evenson (1922), *JDS*, **5**, 97, and Reinart and Brown (1953), *CDICJ*, **32**, 30.

RECORDING MILK. This is a method of recording the yield of every cow, preferably at every milking. At intervals an official visits the farm to check the record sheets and to sample for butterfat and sometimes other tests. To the business man this would seem an obvious thing to do, but only about 20 per cent. of cows in England and Wales are recorded at present. Naturally these cows belong to the most efficient and interested producers, and the average yield of " milk recorded " cows is 778 gal. a year, about 200 gal. higher than the average for non-recorded cows. *See* Agriculture; Milk marketing; Quality payment.

Ref.: M.M.B. (1953), Rep. Prod. Div. No. 4.

RED MILK. A red colour in milk may be due to the presence of blood, as in acute clinical mastitis (p. 660) or to the growth of micro-organisms such as *Serratia marcescens* (*B. prodigiosum*) or certain yeasts. *See* Colour faults.

RED SPOT. *See* Cheese, p. 182.

REDUCING POWER OF BACTERIA. Practically all bacteria have some reducing power (*see* Oxidation-reduction potential) but this property varies greatly with the different species and is considerably influenced by the medium, especially by the sugar content. In milk the lactose-fermenting streptococci, coliforms, and staphylococci are the most powerful reducers, and these organisms are usually chiefly responsible for the reduction of methylene blue (p. 698) and resazurin (p. 904) in dye reduction tests. Broadly speaking, reducing power, acid production and loss of keeping quality go together. Milk is usually initially at an E_h of about + 0·2 v. and the lactose-fermenting organisms mentioned bring this down to about − 0·2 v., methylene blue being reduced at about 0 v.

Refs. : Stephenson ; Wilson *et al.* ; Jones and Davis (1944), *SAB*, p. 38 ; Hobbs (1939), *JDR*, **10**, 35.

REDUCTASES. A general term applied to enzymes which have the power of reducing or decolorising methylene blue and other O-R dyes. Practically all living tissues possess this property and so contain reductases. *See* Enzymes.

Ref. : Stephenson.

REDUCTASE TEST. The old name for the methylene blue test (p. 698).

REFRACTIVE INDEX. When a ray of light passes from one medium (*e.g.* air) to a more dense medium (*e.g.* milk serum or butterfat) at any angle other than perpendicularly it is bent towards the normal. The ratio of the sines of the angles of the incident and refracted light is known as the refractive index

$$\frac{\sin A}{\sin B} = \text{R. I.} \quad \text{(Snell's law.)}$$

This refraction varies according to the wave length of the light and it is usual to work in terms of sodium light (5893 Ångstrom units).

It follows from the above equation that when light is incident at a sufficiently wide angle from the more dense medium in which the velocity is slower, the light becomes totally reflected because sin 90° = 1 and

$$\frac{1}{\sin \theta} = \text{R.I.}$$

This angle θ is the *angle of total reflection* and is used as the basis for measuring the R.I. The original Abbé refractometer forms a layer of the liquid between two prisms working at constant temperature, the reading being made by adjusting a telescope until the border of the shadow is over cross-lines in the field, the reading on the scale then being read.

The Zeiss butyro-refractometer is essentially the same instrument.

It is essential to work at a known temperature and to calibrate the apparatus either with distilled water (R.I. = 1·3334 at 15° C.) or mono-bromonaphthalene (R.I. = 1·658 at 15° C.).

Refractometric methods have not been so widely developed here as on the Continent and in America. *See* Condensed milk.

Refs.: Richmond; Williams, K. A.

REFRIGERATION IN THE DAIRY INDUSTRY. Apart from such faults as oiliness, " cardboard flavour ", and similar oxidative changes catalysed by light, copper, etc., and faults due to the inherent enzymes of milk, such as lipase, the commercial spoilage of milk is always due to bacterial growth. It is well known that the keeping quality of milk is mainly a function of the temperature at which milk is held, as up to a certain point micro-organisms grow faster the higher the temperature.

Many such figures are available, and it may be said, broadly speaking, that milk does not deteriorate below 43° F., and 55° F. is the " critical temperature " above which spoilage of milk takes place with increasing rapidity.

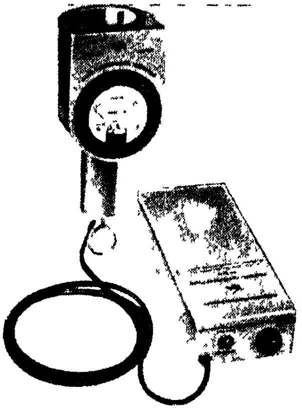
Now it is observed that milk held at different temperatures " goes bad " in different ways, and this is due to the fact that different temperatures favour different types of bacteria. The effect of holding an average milk at different temperatures on the resultant flora is shown in Table Rf I.

TABLE Rf I

PREDOMINATING MICRO-ORGANISMS IN MILK HELD AT DIFFERENT TEMPERATURES

(*Various authorities*)

Temperature		*Types predominating*
° *F.*	° *C.*	
Under 41	Under 5	*Pseudomonas* (fluorescent bacteria)
41 to 50	5 to 10	*Proteus*, *Micrococcus*, alkali-forming rods
50 to 59	10 to 15	*Aerobacter* (aerogenes bacteria) and *Streptococcus* (plant types)
59 to 86	15 to 30	*Streptococcus* (chiefly *Str. lactis*)
86 to 104	30 to 40	Coli-aerogenes bacteria (*Escherichia* and *Aerobacter*) *Streptococcus* (all types), and *Lactobacillus*
Above 104	Above 40	*Str. faecalis*, *Str. thermophilus*, and *Lactobacillus*



[*By courtesy of* " *Dairy Industries* "

FIG. RA 2.—*The Rapid Abnormality Indicator.*

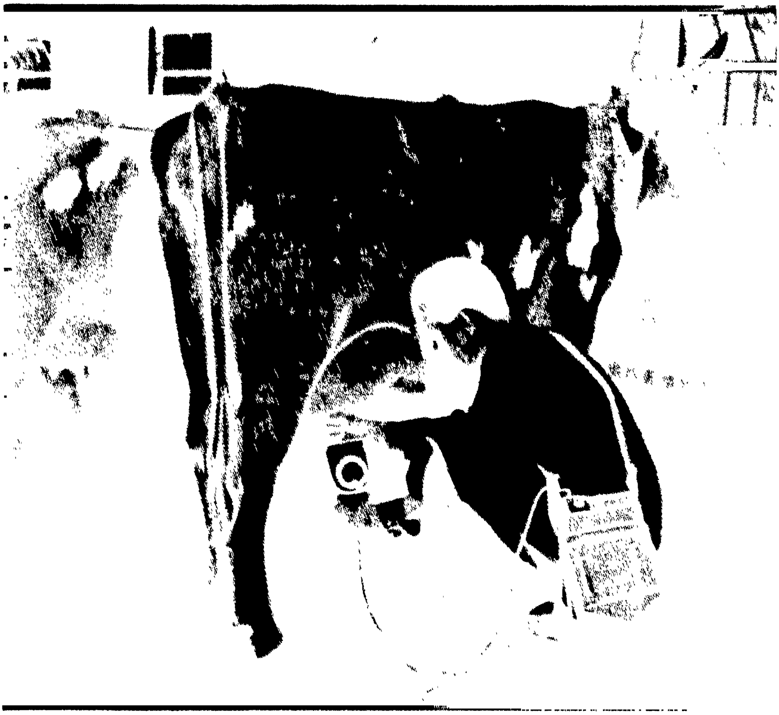


FIG. RA 3.—*Drawing the Milk.*

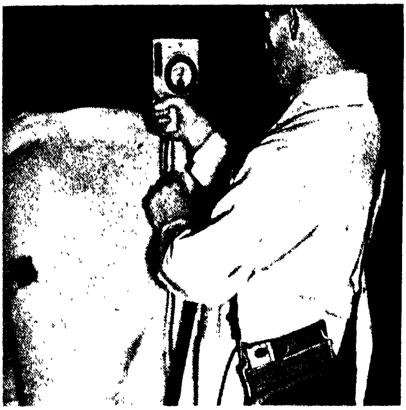
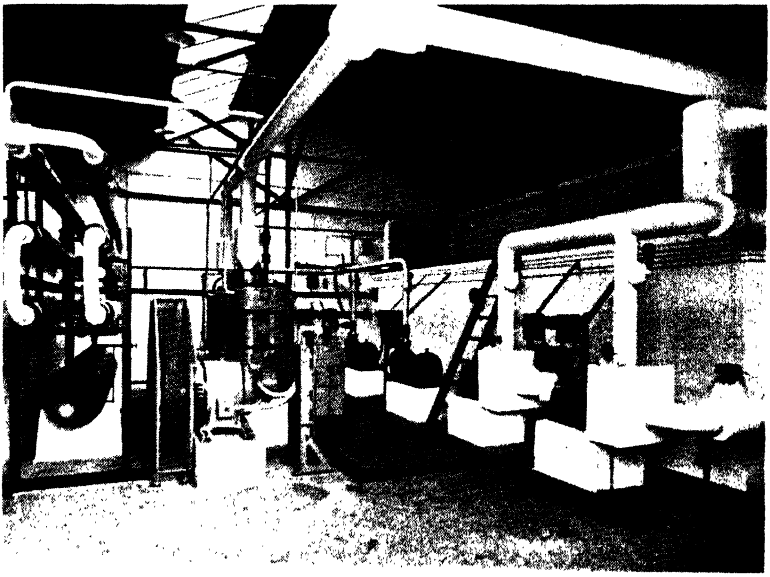


FIG. RA 4.—*Filling the Electrode Chamber and Reading the Conductivity.*



[*By courtesy of York Shipley Ltd. and Express Dairy Co.*

FIG. Rf 2.—*Modern Refrigeration Plant in Creamery.*

The types predominating below 10° C. attack the protein in the milk and turn the latter alkaline; above 15° C. sugar (lactose) is fermented to produce lactic and other acids. Hence, cooled milk when it goes bad tends to become " stinking ", and uncooled milk curdled by acid. Many types growing at moderate temperatures can also clot milk at a neutral reaction by " rennin " enzymes.

Moreover, the *Pseudomonas* types can grow at 0° C. or lower, so that milk will keep only a limited time even at quite low temperatures. Milk is, unfortunately for the dairy industry, an excellent medium for the growth of many bacteria; in some foodstuffs containing a much lower moisture content and having a high osmotic pressure, the combined effects of cold, low moisture, and high osmotic pressure may serve to keep the product almost indefinitely.

It is important to remember that cold will not destroy bacteria in the way that heat does. Holding milk at 0° C. has no significant destructive effect on bacteria: its action is mainly that of restraining growth and metabolism (or chemical activity). Bacteria have been known to survive such extremely low temperatures as those of liquid air and liquid hydrogen. There is, however, a slow destruction of bacteria at low temperatures, but the rate varies with the type of organism and the conditions. Available evidence suggests that it is not cold as such which kills the bacteria, but associated effects as mechanical crushing consequent on crystallisation. There is thus no critical low temperature corresponding to the thermal death point (that temperature required to kill *all* the bacteria in a medium under prescribed conditions), and the effect of cold is markedly dependent on the nature of the solution in which the bacteria are immersed.

The question now arises—to what extent must milk be cooled for commercial purposes ? Must every small retailer and producer install a refrigeration plant ? The cost of refrigerating milk may well be of great significance to a small producer. (By refrigeration is meant the production of cold by ice or artificial means; by cooling, the use of a water supply to bring the milk down to within a few degrees of the temperature of the water which should be below 55° F.) It may be said that for a producer supplying a local market, refrigeration is not essential, as the life of the milk rarely exceeds 24 hr. (Cooling must always be done.) *If milk is to be sent any distance, however, refrigeration is essential.* The milk should be cooled to 38° F. and the cost of this works out at about ½d. per gal. The 1949 Regulations require pasteurised milk to be cooled to a temperature not exceeding 50° F. (*see* Legal aspects).

While it is desirable to avoid contamination at all stages in the handling of milk, the earlier the life of the milk the more important it is to prevent bacterial contamination. Any given contamination a few hours before consumption is not so serious as immediately after production. The weakest link in milk-control work is on the farm, where conditions obviously make bacterial cleanliness a difficult problem. The small dairy also constitutes a " weak link " in the chain. Small-scale refrigeration may easily be expensive, and brine cooling on the farm may not be an economic proposition for the ordinary producer. If milk is sent off only once a day, good water cooling (*i.e.* to 60° F. or less) is essential in summer. Where the water supply does not permit this, it is obviously desirable to install a refrigerating plant, or to ensure the milk is refrigerated locally (*see* Cooling).

Effect of Refrigeration on Keeping Quality. The following figures illustrate the rise in temperature under practical conditions of transport in 10 gal. churns from Reading to London over a period of 8 hr.: temperature at Reading (average) 66° F., temperature at London 75° F.; water-cooled milk rose from 57° to 64° F., brine-cooled milk rose from 44° to 58° F. It is evident that, although refrigerated milk rises in temperature more rapidly, it is still at a great advantage compared with ordinary water-cooled milk (*Bull. Min. Agric.* No. 31 (1937)).

Experiments to ascertain the value of refrigerating milk have also been carried out at Reading. Thus, milk was held at 45° to 50° F. for 12, 24, and 36 hr., and then the keeping quality determined by holding at 60° F. in the usual way. The following results were obtained: control milk (not refrigerated), keeping quality 57 hr.; milk refrigerated for 12 hr., keeping quality 70 hr.; for 24 hr., keeping quality 78 hr.; for 36 hr., keeping quality 86 hr. It is evident that a point will be reached at which further refrigeration will be without effect. Clean milk (plate count less than 5000 and coli absent in 1 ml.) will keep about 7 days at 45° F., but only 3 days at 60° F. and 2 days at 70° F. (W. A. Hoy, Private communication.)

Freezing milk as a method of storage and for transport purposes has not been adopted commercially for the following reasons: (i) The cost of freezing milk is relatively high. (ii) Changes in the physical structure and taste occur. (iii) Frozen dairy produce may go bad rather quickly when thawed. This last phenomenon may be ascribed to the gradual growth but slow metabolic activity at low temperatures, followed by greatly increased metabolic activity (rate of chemical change) at the higher temperatures. *See* Clean milk production.

Ice Cream. This is the only dairy product normally held and sold below the freezing-point. It is generally accepted that significant bacterial growth does not take place under these conditions. *See* Ice cream.

Butter. Storage of butter at low temperatures is a well-recognised commercial proposition. It is of interest to record that certain faults may be accentuated by very low temperatures. Thus, Hiscox (1936), *JDR*, **7**, 238, has isolated from areas of blackish discoloration in refrigerated butter a *Pseudomonas* (small rod-shaped organism) which grows over a wide temperature range, but only produces a blackish pigment below about 15° C. (60° F.).

Such a discoloration, therefore, would only occur in butter kept chilled, because, although the organism would grow in butter at ordinary temperatures, pigment would not be formed. It is generally found that low temperatures favour micro-organic pigmentation.

Mould growth cannot be prevented by the low temperatures in normal use; thus a temperature of − 23° C. is required to stop the growth of *Oospora lactis*. Bacteria in butter, however, are more susceptible to the restraining action of cold, especially when the inhibitory action of salt is superimposed. Thus, American workers found that in unsalted butter at 21° C. a rapid increase in bacterial numbers occurred; at 7° C. a less rapid growth took place. In salted butter there was a tendency for bacteria to increase in numbers at 21° C., and to decrease at 7° C. (*Iowa Agric. Expl. Sta. Res. Bull.* 134.)

Refrigeration has also been found extremely useful in the pre-churning treatment of cream. Controlled chilling is also an important device in securing a good body for cream. *See* Cream.

In New Zealand the lack of refrigeration in the early days of the dairy industry (before 1896) resulted in the development of the cheese industry, because this product is not so dependent on refrigeration as butter. During shipment butter is usually held at about 12° F. and cheese at 40°-50° F.

Since 1922, when the direct expansion ammonia cooler came into use, a greater efficiency has been possible, but this has not been an unmixed blessing. It has been found that slow cooling may result in a lack of spreadability, due, presumably, to a crystallisation of the fat. Too high a churning temperature will give a reduced churning time, but may also result in a soft and streaky butter. Too low a temperature gives a hard butter that may finally show a greasy texture. (Valentine (1936), *NZJ Ag.*, **52**, 213.)

Changes in butter held at different temperatures may be summarised as follows: 40° to 60° F. rapid changes may take place, especially if poor-quality cream has been used; 30° to 40° F. changes are somewhat slower, but staleness, rancidity, and fishiness may develop; 20° to 30° F. doubtful quality cream will give a butter showing signs of spoilage in 5 to 7 weeks; 10° to 20° F. changes are very much slower, but fishiness may develop in salted and unsalted butter; 5° to 10° F. off-flavours are checked almost indefinitely. *See* Butter.

Cheese. Refrigeration has not hitherto been " taken up " extensively by the cheese industry. In Canada it has been found that the cold curing of cheese led to an improved quality and lessened the loss from shrinkage. In New Zealand during the hot summer of 1934-35, the temperature of the curing rooms sometimes exceeded 80° F. As a result, melting of the fat took place and the cheese developed a sandy, gritty body.

In America an experiment was made holding cheese at temperatures from 5° F. up to 60° F. It was found that cheese ripened at 40° down to 28° F. were superior to those held at over 40° F. Above 40° F. the cheese were progressively inferior. The differences were most noticeable in flavour, less in body and texture. Cheese held at 5° F. were frozen hard, and after 6 months had developed serious faults in flavour, body, and texture. Cheese freezes at from — 4° C. to — 14° C., depending on the age, salt, and moisture content of the cheese. Freezing has no effect on flavour, but makes the texture crumbly ; the normal texture is usually recovered on thawing. The surface-drying of cheese is, however, affected and affords a method of detecting cheese that has been frozen. (Sommer (1928), *JDS*, **11**, 9.)

At one time it was thought that cold-curing or low-temperature ripening was injurious and produced a bitter cheese, but there is no experimental evidence for this.

The practice of cold-storing cheese is becoming more popular, and has been used by makers to tide over a period of low prices. Controlled transport temperature (45° to 50° F.) is practised by New Zealand and Canadian exporters. Ventilation is an important point in this technique, as its absence may lead to " soft crowns ".

Temperature conditions for Cheddar ripening may be summarised as follows: below 28° F. inadvisable ; 28° to 40° F. ideal ; 40° to 55° F. economically best ; 55° to 65° F. rather high ; over 65° F. harmful. Humidities vary, but 85 per cent. is a fair average ; below 70 per cent. cracking may take place.

See also Psychrophilic bacteria; Stability.

Refs.: Davis (1951), *SAB*, **14**, 216 (cold on micro-organisms); Sekhar and Walker (1947), *SAB*, p. 24 (psychrophiles); Davis (1951), *D*, **68**, 327; (1952), *F*, **21**, 467; Norman (1950), *JSDT*, **4**, 33 (direct expansion systems); Thiel (1948), *JSDT*, **1**, 199; Stonebanks, 202 (farm); Taylor, 212; Milligan, 219 (industry).

REFRIGERATION EQUIPMENT. Refrigeration deals entirely with heat, and is the process of lowering the temperature of a substance below that of its surrounding atmosphere. The heat-absorbing body, or refrigerant, must be at a temperature lower than that of the substance to be cooled, because heat flows only from a body at a higher temperature to a body at a lower temperature. Heat extracted from the body being cooled by the refrigerant must be carried away and delivered to the atmosphere.

If the lower temperature of a body is to be maintained, the body must be surrounded by insulating material, so that the heat cannot return to it. The unit of heat is the British Thermal Unit (B.Th.U.) and is the heat required to raise the temperature of 1 lb. of water 1° F., at atmospheric pressure. The *specific heat* of a substance is the number of B.Th.U. required to raise the temperature of 1 lb. of the substance 1° F.

The specific heat of water has been adopted as a standard, and the specific heat of any other substance, either solid, liquid or gas, is determined experimentally by comparing it with that of water, the latter being taken as 1.

Specific heat expresses the heat-holding nature of a substance, compared to that of water.

Sensible Heat. Heat added to, or taken from, a substance without causing a change of state, will cause an increase or decrease in temperature. This increase or decrease can be measured by a thermometer.

Latent Heat. When the temperature is reached at which heat added or subtracted does not cause a further change in temperature (as at the freezing or boiling point of water), a change in state takes place upon a further addition or subtraction of heat. The heat necessary to cause 1 lb. of a substance to change its state, at the freezing or boiling temperature, is known as the *latent heat* of the substance.

The Unit of Refrigeration (now almost universally adopted) is the American unit of 1 ton of refrigeration, and is equivalent to the amount of heat absorbed by the melting of 1 ton (2000 lb.) of ice at 32° F., into 2000 lb. of water at 32° F. in 24 hr.

The latent heat of ice is 144 B.Th.U. per lb., therefore the amount of refrigeration at 32° F., melting into water at 32° F., is 2000 × 144 or 288,000 B.Th.U. A refrigerating plant of 1 ton capacity will therefore eliminate 288,000 B.Th.U. in 24 hr., which is equivalent to 12,000 B.Th.U. per hr., or 200 B.Th.U. per min.

The discovery of the properties of volatile liquids made possible a continuous process of refrigeration by mechanical means, and those liquids having a low boiling point are used as refrigerants in mechanical refrigeration. Liquids which change from a liquid to a gas after absorbing heat are known as primary refrigerants. Brine, air and chilled water, which act only as heat carriers, are known as secondary refrigerants or coolants.

The boiling point of a liquid varies with the pressure; the boiling point is also the condensation point for that pressure. At atmospheric pressure, water boils at 212° F.; at 28 in. vacuum it boils at 100° F., and at 100 lb. per sq. in. gauge pressure, it boils at 338° F.

The volatile liquids used in mechanical refrigeration are:

Ammonia	NH_3
Carbon dioxide	CO_2
Methyl chloride	CH_3Cl
Freon 12 (F. 12)	$C\,Cl_2F_2$
Sulphur dioxide	SO_2

At atmospheric pressure:

	Boils at
Ammonia	− 28° F.
Carbon dioxide	− 109° F.
Methyl chloride	− 11° F.
Freon 12	− 18·5° F.
Sulphur dioxide	+ 14° F.

Because of these low boiling points, these substances do not exist as liquids at ordinary atmospheric temperatures and pressure. They can be changed to a liquid by confining them under pressure and cooling the gas to the boiling-point for that pressure. This pressure-temperature relation is the basis of mechanical refrigeration.

Ammonia, having a high latent heat value, is the most commonly used refrigerant. One lb. of liquid ammonia at 5·5° F. is capable of absorbing its latent heat or 564·6 B.Th.U. by which it is changed from a liquid to a gas with no change in temperature. One lb. of ice will absorb in melting only 144 B.Th.U. and sulphur dioxide will absorb only 169·25 B.Th.U. per lb. when at 5·5° F.

The Mechanical Refrigeration Cycle. There are four essential parts in a mechanical refrigeration system. They are varied in design, but the principles of operation remain the same (*see* Fig. Rf 1, p. 899).

In a simple mechanical refrigerating system as used in a dairy, the four essential parts are: (1) The *evaporator*, where the ammonia absorbs the heat from the brine or water (whichever secondary refrigerant is used) and boils to a gas. (2) The *compressor* where the ammonia gas is compressed and its temperature raised so that it can give up its heat. (3) The *condenser* where the heat in the gas is given up and carried away, and the ammonia thereby changed to a liquid. (4) An *expansion valve* or orifice through which the liquid ammonia pressure is reduced, so that the ammonia can repeat its process of absorbing heat. The compressor and condenser are really ammonia-reclaiming devices, because a drum of liquid ammonia, connected to an expansion orifice, would provide refrigeration, but the ammonia would be wasted and the method highly expensive. It is, therefore, cheaper to use mechanical power and cooling water to reclaim the ammonia and make the refrigerating process a continuous one.

Refrigeration in the Dairy. Milk after pasteurisation at 145° or 161° F., must be cooled as quickly as possible to not more than 50° F. In practice it is necessary to cool to 40° F. in summer and 45° F. in winter. *See* Cooling; Legal aspects.

The initial cooling is carried out by passing the milk through a " heat exchanger " where it gives up some of its heat to the raw milk, on its way through the exchanger to the pasteuriser, or by passing it over a tubular cooler, through which mains water is flowing.

As the temperature of the pasteurised milk cannot be reduced much below 60° to 75° F. by the initial cooling, the final cooling must be carried out by means of refrigeration.

This may be done in one of three ways : (A) By passing the milk over a tubular cooler of the direct expansion or flooded ammonia type. (B) By passing the milk through a " heat exchanger " with calcium chloride brine at from 25° to 30° F., in circulation on the opposite side of the " plates ". (C) As (B) but circulating chilled water at 32° to 35° F. in place of the brine.

The milk leaving the final cooler at 40° F. is passed to the filling machine, where it is bottled and capped. The bottles are then crated and placed in a cold room, held at an average temperature of 40° F., until required for distribution.

A typical modern refrigeration unit in a large dairy is shown in Fig. Rf 2.

Cold Storage Room for Milk. The modern way of cooling the milk storage room is by means of a separate refrigerating plant, automatically controlled.

The evaporator or cooler can be of varied design, but the most efficient type is a nest of coils enclosed in a galvanised sheet casing with a fan fitted in the top section.

The air is drawn over the coils and cooled, and discharged through suitable cowls at high velocity across the room : the return air enters the casing at the bottom. The evaporator coils operate on the flooded ammonia system.

The advantage of using high velocity air in the room is that it reaches all parts of the room and maintains an even temperature throughout.

It is essential, however, that the crates are not stacked to the ceiling and that passage ways are left for the return air to reach the cooler casing.

The Maintenance and Control of Refrigerating Plant. Most small and some large refrigerating plants are automatically controlled by a thermostat placed in the brine or water-cooling tank. The thermostat usually has a range of three degrees, that is to say, it will start or stop the compressor when the brine or water temperature rises or falls, one and a half degrees, above or below, the pre-determined temperature. Brine should not be circulated through the exchangers or milk coolers at a temperature lower than 25° F., otherwise there is the possibility of the milk freezing on the " plates " or cooler. In practice, however, brine is often run at less than 25° F. in summer in order to have available a reserve of refrigeration. When using brine, it is essential that its density, and *p*H value, are checked once a week. *See* Brine.

If chilled water is used as the secondary refrigerant, it is not advisable to attempt to reduce its temperature below 35° F., otherwise the water will be frozen on the exaporator coils. Some types of chilled water equipment are now designed to operate at 32°-35° F. If a chilled-water plant is automatically controlled, the thermostat must be of the sensitive type, operating in a range of one degree.

Each time a heat exchanger is opened up for cleaning, a certain amount of brine is lost, and there are small, but unavoidable, leaks from pump glands. Water is added to the tank to make up for these losses, but unless the requisite quantity of calcium chloride is added from time to time, the density of the brine will become so low that it will be liable to freeze on the evaporator coils.

The sp. gr. of the brine should be about 1·2. Brine may be acid, neutral or alkaline, and the unit of the acidity condition of the brine is called the *p*H and this is an absolute measure of the degree of acidity or alkalinity. For any solution the *p*H value will usually fall between 0 and 14 ; a *p*H of 0 indicates a very strong acidity and a *p*H of 14 indicates a very high alkalinity. Midway between these values is 7 which is the neutral point.

Acid brine has a corrosive effect on steel and will cause considerable damage to the tank and pipe lines if this state is allowed to continue. The testing of brine is a very important matter and should be controlled by the laboratory.

If the brine is acid (*p*H value less than 7) a mixture of slaked lime and water should be added, but not more than 1 lb. of lime per 10,000 cu. ft. of brine for each *p*H unit below 7. If the brine is too alkaline (*p*H greater than 8·5) carbon dioxide gas may be added. This can be done by taking carbon dioxide from an ordinary cylinder of this gas, and introducing it into the brine by means of a 5 or 6 ft. length of ¼ in. pipe connected to the CO_2 cylinder by rubber tubing. While CO_2 gas is being added, the brine should be tested every hour, and the CO_2 shut off when the *p*H value has been lowered to 8·5. It is rarely necessary to reduce the *p*H of brine.

OPERATION OF A MODERN REFRIGERATING PLANT, USING AMMONIA AS THE PRIMARY REFRIGERANT. When a new plant is first put into operation, a small quantity of liquid ammonia should be expanded into the suction line or suction manifold, preferably the former and some distance from the compressor, so as to insure against overheating the cylinders. This expansion should be used as long as necessary to maintain normal temperature of the cylinders.

To Start the Compressor. (*a*) Turn on water to the condenser and the compressor jacket. When compressor is in normal operation, water should leave the compressor jacket at about 100° F. (*b*) Open all valves between the compressor and condenser. (*c*) Close compressor discharge valve and pump-out valve ; open by-pass valve wide and suction valve half a turn. (*d*) Start the compressor ; as soon as it is up to speed, open discharge valve and close by-pass valve simultaneously. (*e*) Open suction valve slowly. (*f*) Open valves between the condenser and the evaporator so as to allow liquid to flow to the float regulators or expansion valves. If the latter are used, they should be regulated for the desired suction pressure. Do not allow liquid ammonia to enter the compressor cylinders.

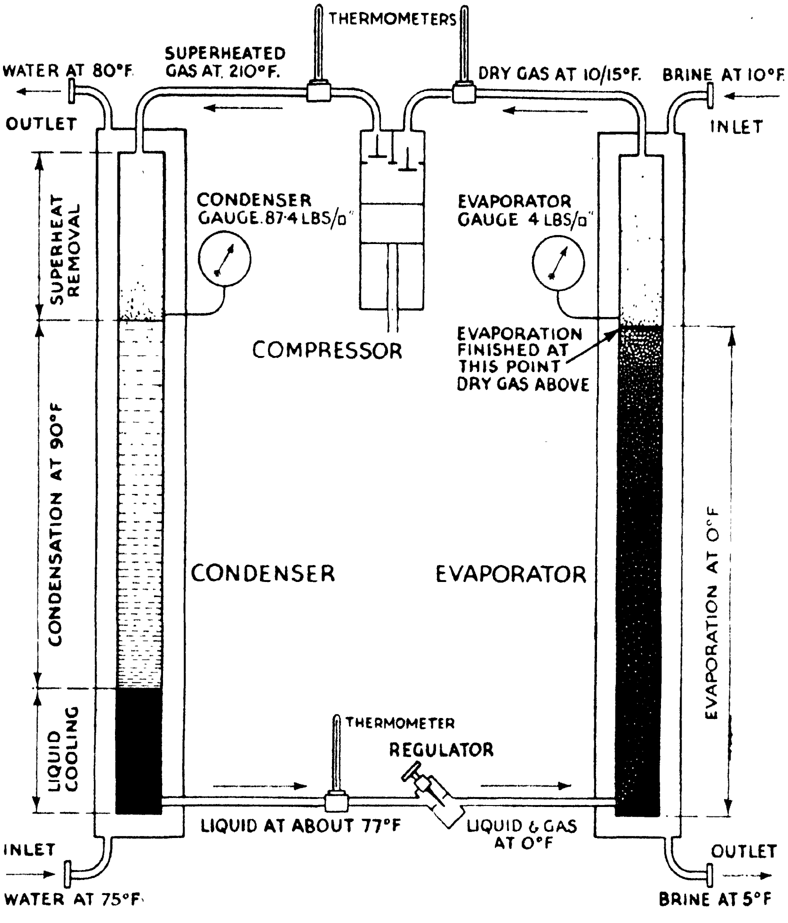
To Stop Compressor. (*a*) If the evaporator is fed by any means other than a high-pressure float ammonia regulator, close the liquid stop valve between the condenser and the evaporator. (*b*) Close suction valve and immediately stop the compressor. (*c*) Close discharge valve. Do not pump back on evaporator prior to stopping the compressor.

The normal suction pressure in a plant, operating with brine as the secondary refrigerant, is 28 to 34 lb. per sq. in. (15° to 20° F. evaporating temperature). If water is used as the secondary refrigerant, care must be taken to see that the suction pressure does not fall below 45 lb. per sq. in. (30° F. evaporating temperature) otherwise the water will freeze on the evaporator coils.

The normal condensing pressure is 155/160 lb. per sq. in., and if the condensers have the correct amount of cooling surface, the pressure in the summer months should not exceed 170 lb. per sq. in.

Adding Oil to Crankcase. To add fresh oil to the crankcase, use the hose connections provided for this purpose, and attach it to the oil-charging valve located on the crankcase. Close suction valve and pump a slight vacuum in the crankcase, insert the hose connection to the bottom of the oil container, and open the oil-charging valve slowly. The oil will then be sucked into the crankcase. Take care to close the oil-charging valve before the end of the hose is entirely uncovered so as to prevent air entering the compressor.

Pumping out for Repairs. If it becomes necessary to pump out any part of the system for repairs, only an engineer experienced in handling ammonia should attempt to do this.



[*By courtesy of J. & E. Hall Ltd.*

FIG. Rf 1.—*Diagram Showing Working of Gas Compression Cycle (Temperatures and Pressures refer to Methyl Chloride).*

The first thing to be considered before pumping out any part of a system, is the available surplus capacity of the container into which the ammonia is to be pumped.

To pump out a condenser in a plant equipped with a receiver: (*a*) Close the liquid outlet valve from the receiver, and allow the evaporator to pump out slightly, then stop the compressor. Caution: do not allow the receiver to fill completely—be sure there is at least some gas space above the liquid. (*b*) Close the liquid stop valve between the condenser and receiver and also the valve in the equalising line between the condenser and receiver (if an equalising line is fitted). (*c*) Shut off the condensing water, and with closed type condensers, drain out all water to prevent it from freezing in the tubes. (*d*) Close discharge and suction valves and open the pump-out and by-pass valves. (*e*) Start the compressor, pump a 15 in. vacuum in the condenser and stop the compressor. As soon as the compressor comes to rest, close the pump-out and by-pass valves.

To pump out a condenser which is constantly drained by means of a high-pressure float ammonia regulator, simply close the liquid stop valve between the condenser and float regulator and proceed as above.

To pump out a condenser which is also used as a receiver, if the evaporator will not hold the ammonia which is stored in the condenser and still leave sufficient gas volume for safety, it will be necessary to secure ammonia cylinders and drain out the surplus liquid before pumping out the condenser as outlined above. Caution : when taking ammonia out of a system and storing it in ammonia cylinders, extreme care must be exercised in weighing the cylinders both before and after they are filled in order to prevent over filling.

After repairs have been made, carefully pump out all air from the parts which were opened up. To pump the air from a condenser, which has been open, close discharge, suction and by-pass valves, then open pump-out valve and remove the plug from the purge opening on the manifold. Operate the compressor until a 25 in. vacuum is obtained in the condenser. Then stop the compressor, and as soon as the flywheel comes to rest, replace the purge plug and close pump-out valve.

Care of Compressor. After the compressor has been in operation for a week, the suction strainer should be cleaned and thereafter once a year. To clean suction strainer : (*a*) Close suction valve and pump a 15 in. vacuum in the crankcase. (*b*) Stop the compressor and as soon as the flywheel comes to rest, close the discharge valve. (*c*) Test the vacuum in the crankcase by opening the oil-charging valve slightly—air should be drawn in through this connection. (*d*) Remove the nuts which hold the strainer cover to the body and remove cover and strainer screen. (*e*) Clean the strainer thoroughly with an air jet and then immerse in a can of paraffin. The strainer should then be thoroughly dried, replaced and the cover securely bolted. (*f*) With the suction, discharge and by-pass valves all closed and the purge plug removed, open the valve in the crankcase pump out line, start the compressor and pump a 25 in. vacuum in the crankcase. Then stop the compressor and immediately replace the purge plug.

It is necessary to clean the oil filter at regular intervals. A gradual decrease in the oil pressure while the compressor is running, indicates that the filter needs cleaning. There are different types of oil filters, fitted to different makes of compressors, and printed instructions, for cleaning the particular type used, are furnished with the compressor.

Maintenance. A compressor should be opened up once a year at least and more often if necessary, and all parts thoroughly cleaned, clearances checked, and the suction and discharge valves reground. The outboard bearing should be carefully watched and compressor oil added at regular intervals as required.

See Brine; Cooling of milk; Electrical equipment; Management of creameries, of pasteurising depots.

Refs. : Farrall ; Min. Agric. (1947), *Technical Aspects of Milk Production in North America*, H.M.S.O. ; *FIM; LCDP;* Cameron Brown (1936), *Refrigeration for the Farm and Dairy*, O.U.P. ; Miller (1949), *Handbook of Refrigeration*, London ; Griffiths (ed.) (1951), *Refrigeration Principles and Practice*, London ; Brown (1952), *JSDT*, **5**, 287; Hall (1950), *DI*, **15**, 813.

REGENERATION. The method of using the heat of a hot liquid, such as pasteurised milk, to warm up a cold, incoming liquid, such as raw milk. The cold milk also serves to cool the hot, thus economising in water. In the modern, efficient pasteurising plant an economy of up to 83 per cent. can be achieved. *See* Pasteurisation.

REGULATIONS. The control of milk and dairy products is exercised through Acts and Regulations, and by Statutory Instruments. Regulations are made by a Minister by the powers conferred on him by an Act.

See Butter; Condensed milk; Cream; Cream, canned; Legal aspects; Milk marketing; Milk powder; Pasteurisation; Sterilised milk.

REICHERT FIGURE OR VALUE. The method for determining the volatile fatty acids in butterfat was worked out by Hehner, Reichert, Meissl and Wollny. Its value lies in the fact that butterfat contains a relatively large proportion of butyric acid (*see* Fatty acids). Reichert obtained values of about 0·3 ml. for artificial butter, 3 ml. for cocoanut oil and 14 ml. for butterfat ($\frac{N}{10}$ NaOH per 2·5 g. fat). It is essential to carry out the distillation under carefully standardised conditions.

Refs.: Soc. Publ. Anal. (1936), *A*, **61**, 404; Richmond; Williams, K. A.

REINDEER MILK. *See* Mammals.

REJECTION TESTS. *See* National Milk Testing Scheme ; Platform testing ; Resazurin tests ; Routine tests ; Testing of milk supplies.

RENNET. All proteolytic (protein-splitting) enzymes, whether from animals or plants, possess the ability to clot milk in varying degrees. Thus rennin is the most powerful, pepsin very active and trypsin (or pancreatin) comparatively weak in clotting milk at its normal acidity (*p*H 6·6). Many of the enzymes are not suitable for cheesemaking, either because they are too weak or do not break down the curd-protein during ripening sufficiently, *i.e.* their proteolytic power is weak. This is particularly the case with the plant enzymes which tend also to produce a bitterness in cheese, generally attributed to " peptones " on somewhat scanty evidence. In some countries vegetable rennets prepared from *Galium verum* (Lady's bedstraw), *Pinguicula vulgaris* (Butterwort), and from the seeds of *Withania coagulans* are used for cheesemaking. The use of plant rennet preparations should overcome the objection of vegetarians to cheese, but is not yet general in this country.

Although most acid-forming bacteria such as the lactic acid bacteria clot milk only by virtue of the acid they produce, many types of bacteria produce a true rennin. The aerobic spore-forming bacilli (*e.g. Bacillus subtilis*) and the Gram-negative rods (*e.g. Bact. prodigiosum*) are the most active in this respect. *See* Sweet curdling.

The power of stomach extract to clot milk was probably discovered accidentally by the finding of clotted milk in the stomach of a killed animal. The ancients knew that the stomachs of many types of animals possessed this power and Aristotle recommended that of the deer. In time it was realised that the abomasum or fourth stomach of the suckling calf was the best, and crude rennet solutions were prepared by soaking this organ in whey. A formula for preparing brine rennet was published in Germany in 1843.

Preparation of Rennet. The commercial enzyme is usually prepared from the fourth or true stomach (abomasum) of the calf.

The lining of the stomach is washed, dried, cut into small pieces, and macerated in water containing about 4 per cent. boric acid at 30° C. for about 5 days. In some countries the use of preservative is not allowed, and so alternatively a brine extract at 15° to 20° C. may be prepared. This preparation is naturally not pure rennin but contains other enzymes present in the stomach lining. A partially purified product is obtained by precipitating the enzymes with alcohol or magnesium sulphate. From a cheesemaking point of view we may regard rennet as a solution rich in rennin but also containing pepsin and possibly trypsin and peptidases. Calf rennet is about seven times as rich in rennin as cow rennet.

Properties of Rennin. Rennin is probably a simple type of protein containing sulphur. One part can clot 5 million parts of milk, but in cheesemaking 1 part of liquid rennet (about 2 per cent. protein) is used to about 5000 parts of milk.

Below 20° C. (68° F.) rennin has a very low activity. From 30° C. (86° F.) to 48° C. (118° F.) it is most active, the optimum being 41° C. (106° F.). Above 50° C. (122° F.) the activity falls off rapidly.

The rate of clotting increases rapidly with small increases in acidity of the milk, as the following figures show :

% lactic acid increase	*Time of clotting*
0	22 hr. 30 min.
0·01	12 hr.
0·025	5 hr. 15 min.
0·05	2 hr. 20 min.

Alkalis considerably retard the clotting of milk by rennin.

Albumin and globulin retard coagulation. This is one reason why mastitis milk clots slowly with rennet. The alkalinity of such milk also contributes to this effect. Boiling the milk previous to adding the rennet, which results in denaturation of these soluble proteins, removes the inhibitory protein effect. Five per cent. " peptone " almost prevents clotting.

A rapid decline in rennet coagulability is observed after milk is taken from the udder. An equilibrium is apparently reached in about 6 hr. This phenomenon is probably due to loss of carbon dioxide and changes in the protein complex of the milk, resulting in an increase in the proteose fraction which retards rennet action.

Roughly speaking, we may say that the time of coagulation is inversely proportional to the amount of rennet added (law of Segelcke and Storch). In other words, the product of *time of clotting* and *quantity of rennet* is approximately a constant. Actually this product is small for small quantities of rennet and large for large amounts of the enzyme.

It is generally agreed that the action of rennin takes place in four stages :

(1) Adsorption of the enzyme on the casein particle.

(2) Change in the state of the casein.

This change proceeds most rapidly at pH 5·4. It has been claimed that a soluble protein is split off from the casein during this reaction. Whether this is an essential part of the change casein-paracasein, or is merely due to proteolysis independent of the change, is not known with certainty.

(3) Precipitation of the changed casein (paracasein) as a calcium salt or complex.

If the soluble calcium (calcium ions) is precipitated with oxalate, this stage cannot be accomplished, although the casein has been changed to paracasein. Boiling (to destroy the enzyme) and subsequent addition of calcium salts results in immediate precipitation.

Berridge has suggested that the change in state of casein produced by rennet action is ultimately a denaturation.

The action of the enzyme is first to destabilise the casein molecule, which is then denatured by moderate heat. The polyvalent cations, *e.g.* calcium, then cross-link the extended polypeptide chains and so render the protein insoluble, or in other words form a clot.

The exact nature of these changes is still not clear, particularly the first stage or destabilisation. At temperatures below 14° C. thermal energy is not sufficient to denature the destabilised casein, but this change can be brought about by some proteases or proteolytic enzymes. Some enzymes, *e.g.* chymotrypsin, papain and pineapple bromelain, appear to be able to bring about both types of reaction, *i.e.* destabilisation and denaturation. (Berridge in Sumner and

Myrback's *The Enzymes*, 1951; Heinicke (1953) *S*, 18th Dec., p. 753); Berridge and Woodward (1953, *JDR*, **20**, 255), and Baun *et al.* (1953, *Arch. Biochem. Biophys.*, **43**, 324) have described methods for preparing crystalline rennin.

(4) Subsequent proteolysis.

The first three take place during the " setting " or coagulation of the milk in the cheese vat. The fourth takes place during the making and ripening periods and largely accounts for the " mellowing " of the curd.

It has been found by studying the effect of rennet on casein at different *p*H values that rennet can bring about at least four enzymic effects, although this does not prove that four separate enzymes are present.

(1) Digestion of the protein due to pepsin, the optimum *p*H being 2.

(2) Digestion of the protein by rennin, the optimum *p*H being 4·7.

(3) Production of amino nitrogen by a peptidase, the optimum *p*H being 6·2. This effect is variable.

(4) Ordinary clotting of milk. This is the combined effect of the enzymic change in casein (optimum *p*H 5·4) and the precipitation of the calcium paracaseinate.

Commercial Rennet. The following may be regarded as essential in a good-quality rennet : (1) constant strength ; (2) good keeping quality ; (3) freedom from fault-producing micro-organisms ; (4) freedom from other enzymes, *i.e.* purity.

In addition to these, the rennet should be reasonably cheap and in a convenient form to handle.

Standardisation of Rennet. There is unfortunately no simple, accurate method of standardising rennet. Producers usually have an arbitrary standard which is transferred from one batch to another. Samples of milk vary so much from one to another that the best plan is to take a sample from as large a bulk as possible. Reconstituted spray-dried milk may also be used. (Mattick and Hallet, 1929, *JAS*, **19**, 452, and King and Melville, 1940, *JDR*, **11**, 184).

Ordinary solutions of rennin or rennet-enzyme in water rapidly lose their activity on account of bacterial action. It is therefore necessary to stop bacterial action by adding preservatives or by drying. Boric and benzoic acids are found in some rennets, although it is doubtful whether this is legal. Commonly a strong solution of brine (*e.g.* 15 to 20 per cent.) is used, sometimes with additional preservative. Such solutions retard bacterial growth for a considerable time, but sooner or later an unpleasant odour is noticed and the strength of the rennet falls rapidly. Bacteriological examination reveals that the solution then contains many thousands of micro-organisms, some of which it is undesirable to have in cheese. Alcohol glycerol rennets are much superior to brine extracts but their cost renders them impracticable. Dried rennet preparations in tablet form may have all the advantages of the alcohol glycerol rennet.

Although only very small quantities of rennet are used in cheesemaking, bacteria can grow at an enormous rate, and cheesemakers should require rennet manufacturers to ensure that their product is free from organisms capable of producing faults in cheese. The most important of these are : (1) coliform bacteria ; (2) putrefactive anaerobic bacteria, particularly *Clostridium ;* (3) yeasts ; (4) moulds.

A rennet, to be above suspicion, should be quite free from these organisms.

Most samples of rennet contain varying amounts of other enzymes, particularly of pepsin. While it is unlikely that traces of pepsin will be deleterious in cheesemaking, appreciable amounts may result in bitter flavours. Cheesemakers should therefore use as pure a rennin preparation as possible.

Finally, convenience in handling implies chiefly ease of measurement. English cheesemakers are accustomed to measure out liquid rennet in a cylinder and then to dilute it with water, but it is as easy to crush a certain number of tablets in water a few minutes before renneting time. Obviously tablets are easier to store, and have other advantages, *e.g.* relatively greater stability in hot weather. *See* Cheese ; Enzymes.

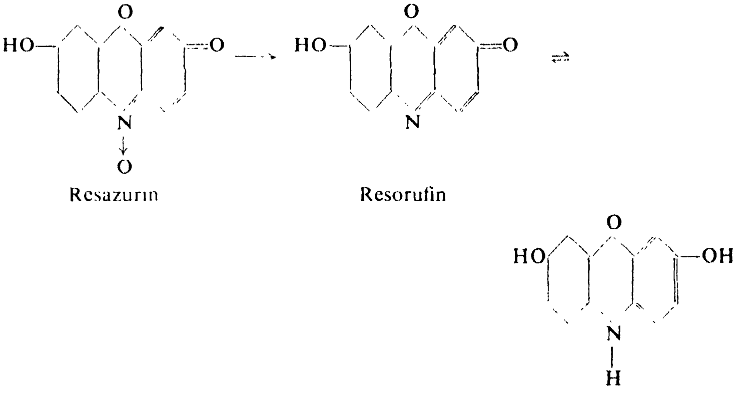
Refs.: Sumner and Somers ; Berridge (1952), *JDR*, **19**, 328 (technique) ; Berridge (1952), *A*, **77**, 57 (standardisation) ; Berridge (1951), *Section on "Rennin" in "Advances in Enzymology"*, N.Y. ; Schulz (1951), *M*, **6**, 74, 112 (coagulation process) ; Berridge (1942), *N*, **149**, 194; Berridge *et al.* (1943), *JDR*, **13**, 145 (rennet from living calves) ; King and Melville (1940), *JDR*, **11**, 184 (viscosimetric test) ; Effront (1917), *Biochemical Catalysts in Life and Industry*, N.Y.

RENNIN. *See* Rennet.

RESAZURIN AND RESAZURIN TESTS. Synthesis and Purification. Resazurin of good quality is now synthesised in this country. All workers appear to use the same method for the purification of the dye, namely, repeated precipitation of the sodium salt from strong sodium carbonate solution, in which sodium resazurate is sparingly, and sodium resorufate readily, soluble. The resorufin content can be minimised by repeated precipitation, and the sodium carbonate by careful drainage.

PROPERTIES. *Resazurin* ($C_{12}H_7NO_4$) is an oxazone which easily loses its oxazone oxygen atom to be reduced to the corresponding oxazine, *resorufin* ($C_{12}H_7NO_3$). This change is not electronically reversible and so cannot be related to a definite Eo value. The oxazine is reversibly reduced, however, to dihydroresorufin.

The change resorufin ⇌ dihydroresorufin occurs over a range of E_h from + 0·150 to – 0·050 v. in milk and has an E_0 of about – 0·020 v. at *p*H 6·9.



Dihydroresorufin

In addition, resazurin is a *p*H indicator, being blue above *p*H 6·8 and red below 5·3. Resorufin is red above 6·4 and yellow-orange below 4·8. As milk which is acid enough to affect resazurin as a *p*H indicator is markedly sour and therefore strongly reducing, this *p*H effect is of no significance in the resazurin test.

Resazurin itself is insoluble in water, but sodium resazurate is about 1 per cent. soluble ; resorufin is more soluble, and sodium resorufate about 5 per cent. soluble.

Sodium resazurate in the pure state is reasonably stable, but in the presence of hydrogen donators such as milk, lactose, etc., is rapidly reduced when activated by sunlight.

Assay of Resorufin. Attempts have been made to assay resorufin by various methods, but so far no simple reliable method has been worked out. Differential solubilities, absorption spectra, and chromatographic analysis all fail to give clear-cut differences between resazurin and resorufin.

In practice, however, the tintometer disc and chromatographic analysis will detect those quantities of resorufin which are large enough to interfere with the test. Small quantities, *e.g.* up to 5 per cent., can safely be ignored. One particularly bad sample started at 4½ on the disc, and chromatographic analysis indicated about 20 per cent. resorufin.

Standardisation. Small variations in concentration, *e.g.* ± 10 per cent., do not affect the test, and all preparations of reasonable purity give similar results in all milks tested. The presence of appreciable amounts of resorufin leads to errors, and bad preparations containing tarry matter are unsuitable.

The following chemical standards have been tentatively adopted for resazurin powder:

(1) The material shall contain sodium resazurate equivalent to 60 ± 3 per cent. free resazurin.

(2) No other dye (apart from traces of resorufin) shall be present.

(3) The residue shall consist only of sodium carbonate and/or sodium acetate and moisture.

(4) A 0·05 per cent. solution in dilute NH_4OH shall give a colourless water-clear solution on reduction with H_2S.

(5) The material shall give in fresh normal mixed Shorthorn milk of 3 to 4 per cent. fat in a concentration of 1 in 220,000 a tintometer disc reading of not less than 6.

Tentative bacteriological standards are as follows:

(6) One ml. of a 0·005 per cent. solution in sterile Ringer shall give a colony count of not more than 10 when plated in milk agar and incubated for 2 days at 37° C.

(7) The material shall behave in all types of milk similarly to the standard materials maintained at the National Institute for Research in Dairying. A difference of ± ½ disc reading at any point is the maximum permissible.

(8) Tablets shall be prepared from the material described above and lactose or other approved diluent only.

(9) When dissolved according to instructions, the solution shall contain 0·005 ± 0·0005 per cent. of " resazurin " as defined above.

(10) The solution so prepared shall conform to the bacteriological condition described (Nos. 6 and 7 above).

With resazurin two distinct reactions are involved, and these normally run consecutively, *viz.*, first, the irreversible reduction of resazurin to resorufin, corresponding to disc 6 falling to disc 1 on the comparator; and, secondly, the reversible reduction of resorufin to dihydroresorufin, corresponding to disc 1 falling to disc 0. This is illustrated in Table Rz 1, from which it may be seen

TABLE Rz 1

ONE-HOUR READING AT MODERATE ATMOSPHERIC TEMPERATURES

Bacterial quality of milk	*Disc*		%		
	Colour	*Reading*	*Resazurin*	*Resorufin*	*Dihydro-resorufin*
Excellent	Blue	6	100	0	0
Very good	Lilac	5	80	20	0
Good	Mauve	4	60	40	0
Fair	Pink-purple	3	40	60	0
Poor	Purple-pink	2	20	80	0
Poor	Pink	1	0	(100)	(0)
Bad	Colourless	0	0	0	100

that each disc number corresponds to about a 20 per cent. change of the resazurin to resorufin. If the milk has a flora which holds it at a high E_h, *e.g.* above + 0·2 v., until the final swift drop, we may safely assume that all the resazurin is reduced before the resorufin is further reduced. In this case we get a full value for disc 1, and the milk may " hang " at this disc number before the final change to disc 0. If, however, the flora is such that the E_h falls steadily towards an E_h of 0, part of the resorufin is reduced before all the resazurin is changed to resorufin. This will result in failure to obtain a full pink corresponding to disc 1, the readings appearing to go from about 1½ to 1 — (pale pink) or ½ (mottled pink-white) without passing through 1. This last point is clearly illustrated by what happens when resazurin is added to a very dirty milk at E_h of below 0. A peculiar mauve colour is obtained which rapidly goes pinkish and then white. It is impossible to match the colours accurately in this case, but as the disc reading is 0 well before 10 min., this point does not affect the accuracy of the test.

With this background we have to ask the questions : " What is it we wish to measure ? Is it total bacterial numbers, or conditions of production, or conditions of production *and* handling, or keeping quality, and, if the last, under what conditions and for what purposes ? Or do we wish to grade down a given percentage of producers ? " Even if we could decide on one of these, we have no fundamental yardstick for assessment of the various tests. For example, the Gerber and other fat tests can be assessed in terms of the Adams or Röse-Gottlieb method, but in no single case can we assess the accuracy of any bacteriological method by a cast-iron standard. If we wish to measure total bacterial numbers with the greatest possible accuracy, we have no option but to return to the plate-count or adopt the direct microscopic count. If, however, we are primarily concerned with keeping quality, then a dye reduction test at low temperatures is obviously indicated. The emphasis nowadays is on keeping quality, and for this reason the test of the future should be the resazurin test preferably at 18° C. and continued to disc ½ or 0, since this form of the test is the most accurate measure of keeping quality.

Summing up, we may say that with the resazurin test we endeavour to measure a multiple complex of the bacteriological and hygienic condition of the milk.

This complex is weighted in the following order : (i) Souring and reducing organisms, especially coli-aerogenes types, streptococci and staphylococci. (ii) Other bacteria. (iii) Cells (due to bad mastitis).

Of these three factors the first is easily the most important, and the last has the least effect on the test. Non-souring bacteria are important because they often produce taints or other faults such as " sweet curdling ", and although they may not sour milk themselves, they may accelerate souring by stimulating acid-forming organisms. From a practical point of view, therefore, the resazurin test is a most useful one.

TABLE Rz II

(Davis and Thomas, 1942)

Mean atmos. shade temp. (° F.)	*Time of incubation at 37° C. (min.)*
40 and under	120
41 to 50	90
51 to 60	60
61 to 65	30
Over 65	15

Temperature compensation. On the question of temperatures or seasonal compensation for dye reduction tests we have three methods available :

(1) Adjustment according to the month of the year, as for T.T. milk (5½ hr. from November to April and 4½ hr. from May to October in the methylene

blue test), and also in the experimental Ministry of Food Scheme, where a more gradual adjustment was attempted.

(2) Alteration of time of incubation according to the minimum night temperature following production.

(3) Alteration according to the mean atmospheric shade temperature of the 24 hr. following production, as illustrated in Table Rz II.

The question will naturally be raised as to the evidence upon which these temperature compensation systems are constructed. It must be admitted that clear-cut evidence for any one system cannot be brought forward. The general problems of the bacteriological grading of milk involve both the *process* or *procedure* and the *purpose*, scientific method can only hope to answer the first question, and for the second we must rely on practical experience and theoretical considerations incapable of formal proof. For example, a rigid standard, say, of disc 0 in 1 hr. at 37° C. would grade down about 1 per cent. in very cold weather and 50 per cent. or more in very hot weather. The advisory side of any scheme must be taken into consideration in formulating the standards, and it is generally agreed that we must frame a scheme so that we can detect and improve in winter those producers who will give trouble in summer. The scheme given in Table Rz II was provisionally adopted in the N.M.T.A.S. in 1942 and modified in 1943 in order to prevent the possibility of requiring an insuperable amount of advisory work during heat-waves, owing to the high proportion of producers that would fall in category C in very hot weather.

Modified Scheme, 1943

Mean atmos. shade temp. (° *F.*)	*Time of incubation* (*min.*)
40 and under	120
41 to 50	90
51 to 55	60
56 to 60	30
61 to 65	15
Over 65	No official testing

Stored bulk milk. Certain features of bulk milk may considerably alter the relationship of resazurin reduction time to bacterial numbers. These are: (1) more standardised flora; (2) more uniform cell-count; (3) oxygen tension.

The first two points are obvious and need no discussion, but the third has to be considered with care. All dye reduction tests depend fundamentally on the oxygen tension of the milk. For producers' milk in 10 gal. churns subject to the usual agitation, sampling and shaking in bottles or tubes, it is safe to assume that aeration is standardised. For bulk milk in depth with variable ratios of milk volume to air space and different times of holding (18 to 36 hr.) conditions are obviously different. It is necessary, therefore, to standardise the aeration, *e.g.* by shaking a given volume a given number of times under standardised conditions. Since the first stage of resazurin reduction is irreversible we may expect resazurin to be less dependent on the oxygen tension than methylene blue. The resazurin and dissolved oxygen may be regarded as competing substrates for the reducing enzymes of the bacteria.

STERILITY OF CHURNS AND BOTTLES. Thomas (1941), *SAB*, p. 47, described a method for testing sterility of churns by this test, and claimed reasonable agreement with the plate-count. Davis and Watson (1943), *DI*, **8**, 415, have modified the method in an attempt to get better matching and a more convenient test. They recommend adding 1 ml. of rinse to 10 ml. sterile separated milk, holding at 22° C. for 24 hr. and then making a 30 min. resazurin test at 37° C. Disc 4 or less fails.

These workers failed to get reasonable agreement between a resazurin test and the plate-count in the case of bottles, and this is presumably due to the different type of flora in bottles, poorly reducing types being more prominent.

Resazurin at 18° C. Test. Hiscox *et al.* (1932), *JDR*, **4**, 105, have shown that the methylene blue test at 15·5° C. is a very good measure of keeping quality.

It is obvious that, as milk is normally held at temperatures of 10° to 20° C., a temperature of 37° C. will not produce the same type of bacterial growth that is found in practice in milk. Usually there is good agreement between results of methylene blue and resazurin tests at 37° and at 15° or 18° C., but in a proportion of cases discrepancies are found.

Such discrepancies are due to the less common distribution of flora, *e.g.* a larger proportion of types growing at 15° but not at 37°, or growing at 37° and not at 15° C. It is evident that in these cases the test at 15° or 18° C. will give the better measure of commercial keeping quality.

There are two serious objections to the methylene blue test at 15° C. In the first place, 15° C. is a difficult temperature to maintain in summer, and secondly, the time of the test is inconveniently long. Thus, if the test is started in the morning, the good milks last until some time during the night or even to the next day, while if the test is started at 5 p.m., bad milks will reduce the dye during the night.

Davis and Watson (1942) have used the resazurin test at various temperatures from 15° up to 37° C. and suggest the adoption of this test at 18° C. for the following reasons :

(1) The most difficult and expensive part of the test at 37° C. is the water bath. A large sink or bath filled at 18° C. will keep this temperature for several hours without attention. The whole problem of water-bath control is thus solved. This aspect is of exceptional importance when equipment is difficult to obtain.

(2) The resazurin test at 18° C. is on the average three times slower than at 37°. Since the recognised standard time for the resazurin test at 37° C. is 1 hr., a suitable time for the test at 18 C. is 3 hr. This is a very convenient time, whether the test is started at 9 a.m., 12 noon, or 2 p.m. If possible, the test should be continued to disc ½ or 0.

(3) A temperature of 18° C. is a fair criterion for the assessment of the keeping quality of milk, which is usually maintained in the household at about this temperature in summer.

(4) Time-lag errors which may be serious in short-time (*e.g.* 1 hr.) tests can be ignored in a 3 hr. test.

Technique. Sufficient water is run into a sink or bath and the temperature adjusted to 18° C. by the addition of warm or cold water. Naturally a thermostatically controlled bath is to be preferred.

TABLE Rz III

Resazurin disc no. after 1 hr. at 37° C.	*No. of samples*	*Average time in hours taken to reach the same disc no. at 18° C.*
6	2	2·75
5½	23	2·6
5	47	3·5
4½	20	3
4	19	3·5
3½	5	4·2
3	4	2·75
2½	5	2·3
2	6	3·5
1½	0	—
1	0	—
½	6	2·8
0	8	2·25

The samples are poured into tubes in 10 ml. amounts and 1 ml. of 0·005 per cent. resazurin added to each tube in the usual way. The tubes are stoppered, and placed in the sink in a wire rack together with a centigrade thermometer. The sink is covered with a tray or piece of wood to exclude light. Tubes are inverted after 1 and 2 hr. and finally inverted and comparator readings recorded after 3 hr.

Unless a fluorescent lamp of the correct type is available care should be taken to start the test in good time, to avoid the necessity for taking readings in a failing light.

One hundred and fifty-five samples of producers' milks from various sources were tested by resazurin at 18° and 37° C. The results are summarised in Table Rz III.

The mean average time is 3·01 hr., so that for practical purposes the resazurin test at 18° C. is three times slower than at 37° C. In other words, after 3 hr. at 18° C. the result usually closely resembles that obtained after 1 hr. at 37° C.

Results show that the majority of discrepancies are due to storing of the samples. The tendency is for stored samples to be reduced relatively more quickly at 18° C. than at 37° C., indicating that this treatment increases the proportion of bacteria active at the lower temperatures.

Davis and Watson have suggested that a temperature of 18° C. could conveniently be adopted as a standard for keeping-quality tests, not only of milk but of milk products. Further, the rather vague " atmospheric temperature " condition required for holding milk samples in some techniques could with advantage be replaced by a definite temperature such as 18° C.

EFFECT OF MASTITIS ON RESAZURIN TEST. That large numbers of cells (leucocytes, epithelial cells and general " cell debris ") can exert an appreciable effect on the reduction of resazurin has been recognised for some years. Ramsdell *et al.* (1935), *JDS*, **18,** 705, seem to have been the first clearly to draw attention to this fact. McClemont and Davis (1939), *JDR*, **10,** 88, showed that the reduction time of methylene blue by udder samples showed a good correlation with cell numbers (catalase test) but not with bacterial numbers. It is clearly established that the reducing effect of freshly-taken udder samples is due practically entirely to cells, whether methylene blue or resazurin is used. When mixed herd milk is 24 hr. old, however, and has grown an extensive flora of contaminants to the extent of 100,000 or more, the reducing effect is due almost entirely to these actively proliferating bacteria, as the cells have lost part of their activity and the cell count has to a large extent been levelled out. Thus, while cell counts of single quarter samples may vary from a few thousands up to 20 millions (still higher in clinical cases), cell counts of mixed herd bulks usually vary from 100,000 to 3 millions ; a cell count in excess of 1,500,000 may safely be assumed to indicate " mastitis " in the herd unless there are other known explanations. Cells are limited in their reducing powers, being of (relatively) large capacity (poising effect), but not of great intensity in the potentiometric (E_h) sense. Thus high-cell udder samples may instantly partially reduce M.B., but the dye is quickly reoxidised by air and the final reduction time may be 12 or 18 hr. When M.B. is reduced by bacteria in milk, the colour rarely, if ever, returns. For these reasons the M.B. reduction time of mixed herd milk is controlled practically entirely by the bacteria, the cell effect being practically nil at 24 hr. Resazurin reacts differently on account of the fact that the first stage is irreversible, *i.e.* resorufin formed by cell reduction stays as resorufin and is not reoxidised by air to resazurin.

The practical problem then is : " What is the extent of mastitis required to lower the resazurin disc number by a given amount—will the ordinary subclinical mastitis that is present in every herd affect the test appreciably, or will only severe and extensive mastitis appreciably down-grade a producer ? "

It has been shown that in high-count milks, below disc 4 in the rapid test, there is no appreciable correlation between cell count and resazurin disc number for any given bacterial count.

As a general conclusion from experiments it may be affirmed that mastitis of the ordinary type and extent commonly found in dairy herds has no significant effect on the resazurin test applied to milks in or near the *salvage* and *rejected* categories. If a producer is graded down on account of mastitis, it is evident that his supply contains a considerable proportion of grossly abnormal milk, if not of actual clinically " mastitis " milk.

We feel, therefore, that the adoption of the resazurin test is advantageous in drawing attention to the existence of serious mastitis in a herd. It is, however, essential that creamery laboratory staffs shall be able to interpret tests correctly and be prepared to " follow up " by testing individual cows on the farm and giving the farmer all possible help in assisting him to reduce the extent of mastitis to negligible proportions.

Finally, it may be pointed out that the real answer to producers who claim that their milk has fallen into the salvage or rejected categories on account of mastitis is that the quality of their milk should never fall to the vicinity of these categories. The standard for market milk is very lenient and no producer who takes reasonable precautions in production will have cause to worry on this score.

Resazurin-Rennet Test. This test is simply a combination of the resazurin test and the rennet test. The latter measures chemical abnormality, and mastitis milk usually clots slowly with rennet on account of high *p*H (low acidity), high globulin, low casein, and low calcium. The reactions of the tests under different conditions are summarised below :

TABLE Rz IV

	Age	*Resazurin*	*Rennet*
Single quarter samples	Fresh	Measures cells	Measures abnormality (very sensitive)
Single cow samples .	Fresh	Measures cells	Measures abnormality (still quite sensitive)
Small herd bulks .	24 hr. old	Measures bacteria (slightly affected by very high cell content)	Detects bad mastitis
Large herd bulks .	24 hr. old	Measures bacteria (slightly affected by very high cell content)	Less sensitive than for small herds
Bulk milks . .	24 hr. or older	Measures bacteria only (cell content fairly constant)	Useless

For the purpose of testing individual quarters on the farm, a rough test, for which a comparator is not essential, can be used. In this case the colour is estimated subjectively as blue, lilac, mauve, pink, or white. It is recommended, however, that a comparator be used and disc numbers recorded.

Method of testing. Just before milking, the tester should go round the herd with the head cowman. Two or three streams are withdrawn from each quarter, and then a sample taken into a test-tube or bottle. Tubes may be labelled by any convenient method. Mixed quarter (*i.e.* single cow) samples may be taken if time is short, but this is not recommended.

The samples are then taken to the kitchen where the testing is most conveniently done. The excess milk over 10 ml. is poured off from each tube. One resazurin tablet and one special rennet tablet (or about 0·06 ml. brine rennet) is added to 50 ml. glass-distilled or faintly acidified tap water.

After thorough mixing and complete solution, 1 ml. of the mixed resazurin-rennet solution is added to each tube of milk, the mixture inverted twice slowly and placed in the wire rack in the water bath adjusted by hand-control of a small spirit lamp to 37° to 38° C. In a rough test all tubes may be put in together and examined at ¼ hr. intervals up to 1 hr. For an accurate test, using a comparator, the tubes should be set up and started 10 to 12 at a time and each batch examined separately as above.

Recording. (1) Rough test. Remove the tubes singly after ¼, ½, ¾, and 1 hr. and record the colour (blue, mauve, pink, white); tilt gently to see if clotted.

(2) Accurate test. Remove the tubes after ¼, ½, ¾, 1, 1¼ and 1½ hr., tilt gently to see if clotted or viscous; if still quite liquid invert slowly and place in comparator and record disc number. If clotted or viscous do not invert. Record rennet reaction as nil (-), viscous (v), soft clot (sC), or clot (C).

It is preferable to use rennet of such strength that the normal milks clot in ½ to ¾ hr. If time is limited, however, there is no real objection to using twice or three times the normal strength. The abnormal milks will always clot more slowly than the sound samples. Milk from really bad quarters will fail entirely to clot with rennet. So many factors affect the clotting of milk by rennet that the correct strength for the desired clotting time can only be found by experiment. Usually about 0·12 per cent. brine rennet (0·06 ml. in 50 ml.) in the 0·005 per cent. resazurin solution will clot normal milk in ½ to ¾ hr. at 37° to 38° when the milk is not more than 3 hr. old.

Interpretation of results. The bad cases will stand out by turning pink in a short time and not clotting in 1 hr. or even not at all.

Usually a quarter sample reducing resazurin quickly, *e.g.* to pink in 1 hr., will clot slowly with rennet, give a high catalase value, give a purple colour to bromcresol purple papers, have low solids-not-fat, and contain mastitis organisms, usually streptococci or staphylococci, in some numbers. Sometimes, however, the results do not correlate and this may be a source of perplexity.

It must be clearly understood that the indirect tests are not specific for mastitis, if by mastitis we mean the presence of mastitis-causing bacteria.

Quick resazurin reduction means a milk high in cells; slow rennet clotting means an abnormal milk, high in *p*H and globulin. If the sample reduces resazurin quickly but clots normally, it may mean that the quarter is in the latent condition of the disease and so will be suitable for treatment.

If the sample clots slowly but does not reduce resazurin it may mean that the quarter has suffered an attack of mastitis in the past. The infection and corresponding high leucocyte content have disappeared, but permanent damage to the milk-secreting cells in the udder has resulted in the secretion of abnormal milk thereafter.

Circumstances may be such that the tester cannot wait for 1 hr. at the farm. The best method is then to cool the samples as soon as possible and leave them in a refrigerator overnight. Udder samples may be tested next day when 18 hr. old. The resazurin-reducing power of the abnormal samples will have fallen somewhat and the rennet reaction be slightly weakened (longer clotting times), but the ability to differentiate the abnormal samples will not be impaired—mastitis milks will still reduce resazurin and clot slowly with rennet.

Although of all conditions mastitis is easily the most important in controlling the physiological, chemical, physical, and bacteriological conditions of milk in the udder, other factors can produce detectable changes. The bearing of these on the resazurin-rennet test will now be discussed. Physiologically abnormal milk can easily be recognised, as all four quarters behave similarly.

It is naturally a matter of great practical importance that physiologically abnormal milks should not be diagnosed as mastitis milks. Fortunately this is usually easy. The farmer knows the stage of lactation of each cow, and this information should always be obtained and recorded when making a resazurin-rennet test. Even if this information cannot be obtained, a comparison of the results on the four quarters will always indicate physiological abnormalities. For example, if all four quarters give milk clotting quickly with rennet, it is almost certain that the cow calved recently. Conversely, if all four quarters give milk that reduces resazurin to a slight extent and clots rather slowly with rennet, it is likely that the cow is in late lactation. The outstanding feature of mastitis is that one or two quarters give milk that is noticeably different from the others.

Strictly speaking, milk producers should not include milk from a cow until at least 4½ days (9 milkings) after calving. The first milk or colostrum is quite a different substance from normal milk, but after 3 days the chemical composition has changed considerably and is similar to that of normal milk. After 15 days the milk may be regarded as normal. During this time (3 to 15 days) the milk is slightly more acid (lower *p*H) than normal milk and so clots more quickly with rennet.

After 8 months or longer the milk in any lactation begins to change. The number of cells gradually increases and the milk gets slightly more alkaline. The effect of this is that in time such milk will reduce resazurin to a slight extent and clot more slowly with rennet. In other words, milk of late lactation behaves like a lightly infected mastitis milk. The behaviour of these physiologically abnormal milks in the resazurin-rennet test is summarised in Table Rz V.

TABLE Rz V

Type	*Cell content*	*Effect on resazurin test*	*Acidity*	*Effect on rennet test*
Colostrum . .	Increased	+	Increase	—
Post colostrum . .	Normal	0	Slightly increased	Accelerated
Late lactation . .	Increased	Slight	Slightly decreased	Retarded
Admixed with blood through injury .	Increased	+	Slightly decreased	Retarded

TECHNIQUE FOR RESAZURIN TESTS. The following tests have been proposed:

(i) The 1 hr. test at 37° C. for routine grading of producers' supplies (Thomas).

(ii) The triple-hour test (Johns).

(iii) The standard (temperature-compensated) test (N.M.T.A.S.).

(iv) The rapid resazurin test (originally 5 min. at 45° C., but modified in 1941 to 10 min. at 37° to avoid necessity for a special water bath and to improve accuracy) (Davis).

(v) The resazurin-rennet test, primarily designed for testing for abnormality in single quarter samples, but also useful for the routine control of producers' supplies, especially where the milk is processed (Davis).

(vi) The resazurin test at 18° C. (Davis and Watson).

The fundamental technique is the same for all these modifications of the test and this will be considered step by step.

(1) ***Sources of resazurin.*** The following approved supplies may be used:

Tablets	*Powder*	
Bengers	Eastman	obtainable from recognised suppliers
Boots	National aniline	

Resazurin should never be bought in solution.

(2) ***Preparation of solution.*** Dissolve 100 mg. (0·1 g.) in 200 ml. glass-distilled water, bring to the boil or steam for ½ hr. (do not autoclave), cool and store in the refrigerator (*stock* solution). Dilute 1 to 10 (*e.g.* 5 to 50 ml.) as required (*bench* solution).

Alternatively dissolve one tablet in 50 ml. sterile cold water. This tablet solution must not be used if more than 8 hr. old.

Either method gives the 0·005 per cent. *bench* solution.

(3) ***Checking the solution.*** The resazurin powder should contain sodium resazurate equivalent to 60 ± 3 per cent. resazurin and only a few per cent. of resorufin. The purity is most easily checked in practice by a reading with the resazurin comparator on fresh-mixed Shorthorn milk of fat content 3 to 4 per cent. If a reading of less than 6 is obtained or the colour is *markedly* deeper or paler than the control (disc) colour, the sample should be rejected. The most satisfactory test is to compare tests with standard materials on a series of milks. Agreement to within ½ disc should be obtained on 98 per cent. of readings ; occasionally a greater difference is obtained, probably due to sampling errors in the milk. This should not occur in more than 2 per cent. of the readings.

(4) ***Sampling producers' supplies.*** The ideal method is to plunge thoroughly all churns with a sterile plunger and take a composite sample. In practice a number of churns (at least $\sqrt{n}$ where $n =$ number of churns) may be sampled by briskly stirring and plunging with a long-handled dipper. Samples may be taken either into a sterile bottle or direct into the test-tube, but the latter method is messy and is not recommended. It is generally considered preferable to test a.m. and p.m. milk separately, but as some producers only send in mixed milk there is much to be said for the practice of making composites of a.m. and p.m. milk (where separate). A test on mixed milk has the advantage of testing two meals at once and bad production conditions for either will be revealed in the test.

Sampling is much easier if two persons take part, one labelling and handling the bottles and the other taking the sample.

Producers' milks should never be tipped before sampling for bacteriological testing. A weigh-tank sample is excellent for chemical tests but may become seriously contaminated by a previous producer's milk.

The sampling of non-creamery senders is a difficult problem and the methods must be laid down by the controlling authority. If possible, sample at the place of production. Never open a bottle or carton in the street.

(5) ***Storage of samples.*** The conditions of storage will be laid down by the controlling authority for certain cases. For other testing it may be emphasised that all tests, especially dye tests, are of little use unless the sample has been aged under standardised conditions. The ideal would be to sample on the farm and hold the sample for, say 24 hr. at a fixed temperature, *e.g.* 18° or 15·5° C. Unfortunately, this is not practicable. The method of compensation for varying atmospheric temperatures adopted by the National Milk Testing and Advisory Scheme (N.M.T.A.S.) is probably the best attempt yet to solve this problem in a practicable manner.

When samples are refrigerated overnight they must first be immersed in ice water at 5° C. or less for at least 15 min. If merely placed in a cold store, the temperature of, say, a 6 oz. sample may not fall to that of the air for an hour or more, sufficient for a dirty sample to deteriorate appreciably.

(6) ***Setting up equipment.*** It is good technique to have everything ready in the laboratory before the samples are brought in. This means : (*a*) water bath at 37·5° ± 0·5° C. ; (*b*) test-tubes labelled and ready in racks (rows of 10) ; (*c*) 0·005 per cent. bench resazurin solution ; (*d*) sterile pipettes and bungs.

(7) ***Setting up the tests.*** The bottles, which should not be quite full, are shaken 25 times with an excursion of 1 ft. This is necessary not only to mix

the sample thoroughly but also to aerate the sample. All dye tests depend fundamentally on the oxygen tension of the milk. If a sample is taken from a bulk which has stood for some time and a dye test performed without this shaking, a low result may be obtained. Moreover, the fat in milk is richer in bacteria than the skim. A faulty sample high in fat will thus also give a low result. After thorough shaking, flame the mouth of the bottle and that of the test-tube with a Bunsen flame that is slightly yellow, and pour milk into the test-tube up to the mark (10 ml.). It is convenient for a second person to add the bench resazurin solution. Either a sterile 1 or 10 ml. graduated pipette may be used. Automatic burettes are difficult to sterilise and should not be used.

Owing to the lag incurred in setting up a large number of tests, after resazurin has been added to 10 tubes the bungs should be inserted and the tubes placed in the bath. Record the time in the laboratory notebook or day-sheet, and proceed to set up the next 10.

(8) ***Matching the colours.*** At 10 min. and at 1 hr., or the prescribed time after the tubes have been put in the bath, remove them singly and record as follows:

Face the comparator to a north window or to a white wall or surface which should be about 3 ft. away. See that the disc glasses are free from dust and moisture, and that the " blank " tube is in place and has been recently inverted. Gently lift the first tube from the bath and examine. If the tube is white except for a pink band or swirl at the top, record 0. If the milk is mottled or streaky white-pink or *very* pale pink, record ½. Otherwise invert the tube gently, wipe with a cloth, and place in the comparator (right-hand side) and revolve the disc until a match is obtained. Match on tint, *i.e.* the degree of redness or blueness, and not on intensity of colour. If the colour is about halfway between two numbers, record the half value. If only slightly above or below a number, routine workers should record that number. Research and other experienced workers may estimate ¼ values (record as, *e.g.* 6 − = 5¾, 4 + = 4¼, etc.), but this is not necessary for ordinary work. If the matching is not good, ¼ values cannot be estimated with certainty. Very rarely a milk may fail to give a good match at any disc number. When this occurs, the method of bracketing should be used. For example, supposing a milk is purple in colour and is clearly less than 4 and greater than 2, such a milk may safely be recorded as 3.

Every tester should make at least 500 matchings before reliance can be placed on the results.

It is an advantage for one person to match the tubes and another to record.

When the set of 10 tubes has been recorded and replaced in the bath it will be nearly time to start on the next 10. Times of setting up, etc., should be recorded for each set of 10 tubes.

Although it may only be necessary for the purpose of the particular routine test employed to record at the end of, say, 1 hr., much useful information can be obtained by recording at 10 min., as described, at ½ hr., and at 1 hr. In any case all tubes should be inverted *gently* before each recording and in any case after 1 hr. This not only ensures adequate mixing of the fat and the best conditions for matching, but also gives the quickest result. Further, a comparison of the rate of change of disc numbers at different times during the test gives valuable information about the nature of the reducing substances in the milk. A convenient method of evaluating this is to take the ratio of the 10 min. or ½ hr. reading to the 1 or 2 hr. reading. Alternatively, the ratio of times required for complete reduction to that required to reduce to disc 4 may be used. It has been shown that this ratio is related to the cell content (as indicated by the catalase test), although the standard deviation is high. This simple device affords a method of picking out the bad mastitis milks and can be linked up with the rennet test and the catalase test.

(9) ***Milk for " blank " tube in comparator.*** Ideally this should be the same milk as that used in the test, but in practice it is sufficient to make a composite

of milk from a few bottles if the supplies are Shorthorn or Shorthorn-Friesian. If pure Friesian, or high fat breeds such as the Guernsey and Jersey, it is essential to put up separate " blanks ". Invert the " blank " tube every ½ hr.

(10) ***Positive and negative controls.*** Usually every batch contains one very good and one very bad milk, and these automatically act as controls. To ensure a negative control, freshly taken good quality milk may be heated to 90° C., cooled and used. Such milk should remain at disc 6 for at least 2 hr. at 37° C.

(11) ***Colour of glass of test-tubes.*** If the batch of test-tubes contains differently coloured glass tubes, difficulties in matching may occur, and in extreme cases an error of ¼ disc may be introduced if, *e.g.* the " blank " tube is of a deep green colour and the experimental tube is of white glass. It is sufficient in practice to see that the test-tubes used are of approximately the same colour glass.

(12) ***Lighting.*** On no account face the comparator to direct sunlight. In the afternoon special care must be taken that yellow sunlight does not strike across the tubes from the side. Ordinary variations in daylight do not seem to affect the comparator significantly provided very dark clouds or a bright blue sky are not used as a background, and the daylight is not fading.

(13) ***Use of comparator in artificial light.*** A specially modified C.I.E. light source and the true " daylight " fluorescent tubes give results not significantly different from daylight (Davis and Newland (1943), *DI*, **8,** 555). The domestic pink type of fluorescent lamp is not " true daylight " and these lamps should therefore not be used.

(14) ***Possible confusion between disc 2 and 1.*** When the resazurin has practically all been changed to resorufin, and some of this has been reduced to dihydroresorufin, the pale pink colour obtained (disc 1 —) is not unlike disc 2 or 1½, and can be confused by the inexperienced. The safest procedure is to hold the tube in the bath a little longer. If the pink colour goes deeper, the original was 2 or 1½ ; if to ½ or 0, then the original disc reading was 1 —.

(15) ***Colour-blind workers.*** It is obviously essential that testers have normal colour perception. Probably the best test is the Ishihara, but the test book is expensive. Roughly about 8 per cent. of men and 2 per cent. of women are colour-blind to some extent. A simple method of checking workers is to cut a number of pieces of differently coloured wool in half and ask the subject to name and match the colours. Greens, browns, and reds are most important, and the wools should be of approximately equal colour brightness.

(16) ***Activating effect of sunlight.*** Although resazurin alone is stable to sunlight, it is readily reduced by sunlight in the presence of milk and other potentially reducing systems. Hence it is important that sunlight is never allowed to fall on resazurin in milk, or on the milk itself.

See Bacteriological grading ; Methylene blue ; National Milk Testing Scheme ; Platform testing ; Routine tests ; Sampling ; Testing of milk supplies.

Refs.: Davis (1940), *DI*, **5,** 18 and Watson (1948), *DI*, **13,** 751 (reviews) ; Higginbottom (1948), *DI*, **13,** 1187 (rejection tests) ; Thomas *et al.* (1948), *DI*, **13,** 351 and 966 ; Watts *et al.* (1948), *DI*, **13,** 31 (winter conditions) ; Armour (1948), *DI*, **13,** 37 (cell effect) ; Edwards and Morris (1947), *DI*, **12,** 648 (heat resistant reducing substances) ; Watson *et al.* (1946), *SAB*, p. 56 (reproducibility) ; Thomas *et al.* (1946), *DI*, **11,** 674 (test for winter conditions) ; Davis *et al.* (1945), *SAB*, p. 52 (effect of temperature on test) ; Thomas and Thomas (1945), *DI*, **10,** 423 (routine test) ; Wood and McKenzie (1945), *DI*, **10,** 177 (rejection standard milk) ; Anderson and Wilson (1945), *JDR*, **14,** 21 ; Barkworth and Jones (1944), *SAB*, p. 44 (colour reading) ; Davis and Jones (1944), *SAB*, p. 40 (differentiation of cells) ; Jones and Davis (1944), *SAB*, p. 38 (effect of pure cultures) ; Thomas *et al.* (1944), *SAB*, p. 28 (routine test as index of K.Q.) ; Egdell and Peregrine (1944), *DI*, **9,** 867 (resazurin and M.B.) ; Thomas and Phillips (1944), *DI*, **9,** 699 (routine test) ; Thomas and Peregrine (1944), *DI*, **9,** 634 (resazurin and M.B.) ; Thomas and Bowie (1944), *DI*, **9,** 335 (cell effect) ; Davis and Newland (1944), *DI*, **9,** 339 (treatment of sample) ; Morris and Edwards (1944), *DI*, 9, 92 (cell effect); Thomas *et al.* (1943), *DI*, **8,** 163 (10 min. test); Davis (1943), *DI*, **8,** 167 (technique); Davis *et al.* (1943), *DI*, **8,** 23, 71, and 115 (general treatment); Egdell and Thomas (1943), *SAB*, p. 53 (resazurin and M.B.); Morgan and McKenzie (1943), *SAB*, p. 64 (as test for mastitis); Morris (1943), *SAB*, p. 28 (thermoduric organisms); Phillips and Soulides (1943), *SAB*, p. 50 (variability); Thomas and Bowie (1943), *SAB*, p. 56 (mastitis and late lactation milk); Provan and Rowlands (1943), *DI*, **8,** 693 (pasteurised milk); Jones and Barkworth (1943), *DI*, **8,** 635 (M.B. and acidity); Davis and Newland (1943), *DI*, **8,** 555 (test in artificial light); Davis and Watson (1943), *DI*, **8,** 415 (test for churn sterility); Barkworth *et al.* (1943), *DI*, **8,** 215 (rapid tests); Barkworth *et al.* (1942), *SAB*, p. 25 (rapid platform tests); Thomas (1942), *SAB*, p. 27 (resazurin at 18° C.); Thomas and Phillips (1942), *SAB*, p. 22 (10 min. test); Morgan (1942), *DI*, **7,** 117 (factory use); Higginbottom (1941), *SAB*, p. 32 (resazurin, M.B. and count); Rowlands and Provan (1941), *SAB*, p. 36 (resazurin for pasteurised milk); Thomas (1941), *SAB*, p. 34 (fresh and aged udder samples); p. 47 (test for churn sterility); Davis (1939), *DI*, **4,** 421 (resazurin-rennet test); (1939), *DI*, **4,** 221 (original form of rapid test); Clegg (1949), *SAB*, No. 2, 69, 79, 87; Thomas *et al.* (1951), *SAB*, **14,** 191 (temp. comp.)

RESEARCH, DAIRY Dairy research was admirably defined by Dampier (1931), *Dairy Research*, E.M B. 44, H.M.S.O., in the following terms:

" Dairy research is the study by scientific methods of the dairy industry and its products and of the fundamental scientific principles underlying its operations." So that the words and phrases in this definition should be entirely unambiguous, he went further and indicated in more detail how they should be interpreted: " The dairy industry begins with the dairy farm, including the growth of fodder, both grass and arable crops the breeding, management and feeding of the dairy herd, the production of milk, the operation of milking and the handling of milk, farm processes for the conversion of milk into dairy products such as butter or cheese, and the storage and marketing of milk and these products. Secondly come the problems of the dealers and manufacturers, who collect milk, transport and distribute it to the retailers, and convert surplus milk into dairy products by large-scale processes. Thirdly, there is the retail trade and the delivery of milk to the consumer. Fourthly, we have the problems of the nutritive value of milk and its products in different forms, together with the medical and public health questions which are involved. Moreover, to obtain a complete survey, most of these problems need studying from two or more different aspects—agricultural, chemical and physical, physiological, bacteriological, statistical, economic and financial."

The omission of any specific mention of the important machinery and engineering aspects both on the farm and in the distributing and manufacturing industry is one that, had Dampier been writing today instead of 25 years ago, would probably not have been made, and the inclusion of the word engineering or machinery as an additional adjective in the last sentence would give us a statement of the modern scope of dairy research to which very little exception could be taken.

There are two interesting aspects of dairy research which should be mentioned at the outset. The first of these is clearly indicated in Dampier's statement, namely, that dairy research does, and must, deal with problems on *both* sides of the farm gate. What happens on the farm is of first importance for efficient distribution and manufacture; the way in which milk is to be utilised determines to no small degree the methods and equipment used, and even to some extent the breeding policy on the dairy farm. Dairy research must, therefore, stretch right across this economically and scientifically important junction between *production* of human food on the one hand and, on the other, its *utilisation* and nutritional value. This can be recognised most easily, perhaps, in the problems associated with milk bacteriology. Nevertheless, of the problems of the milk producer some are concerned only very indirectly with those of the distributor or manufacturer; similarly, modern milk processing and utilisation have a bevy of problems of their own which bear little relation to those on the farm.

The second duality in dairy research is between the immediate or *ad hoc* problems either on the farm or in the industry and the *fundamental* problems associated with each of these fields. This duality, like the one first mentioned, is far from rigid. Whilst quite a number of *ad hoc* problems have been, and are being, solved merely by the application of scientific knowledge already obtained, the attack on some of these problems quickly reveals gaps in our basic scientific or technological knowledge which only fundamental study can remedy. Thus, an investigation at Shinfield on the improvement in the length of life of milking-machine rubber liners brought up basic questions in connection with rubber manufacture, with the solubility of butterfat in rubber, with methods of bacteriological sterilisation of rubber, with milking-machine design, etc. On the other hand, academic studies on the fundamental principles underlying dairying not infrequently have a very practical side; thus, a scientific investigation of the enzymes present in milk led to the well-known phosphatase test for efficiency of pasteurisation.

It would be a serious misconception if it were thought that it was only in the official dairy research institutes or in the laboratories of the big dairy firms that research in dairying was being carried out. Original investigations of dairy problems, large and small, are being undertaken by a wide variety of organisations, and in laboratories of very different types; from the engineering research which goes into the design and production of a modern pasteurisation or spray-drying plant, to the quest by the control staff of a milk-collecting depôt for the causes of persistent milk souring on the farms of some of their suppliers, or the investigation by a nutrition chemist of the National Agricultural Advisory Service of the factors which are causing a fall in milk compositional quality in some part of his province. All such findings as are sound and reproducible add something to the aggregate of new knowledge of dairy science and practice and can be regarded without misgiving as dairy research.

Dairy Research Centres. Whilst in some countries, dairy research of a high standard is carried out in agricultural colleges or in the agricultural or dairying departments of universities, there is now an increasing number of institutes entirely devoted to dairy research. The following list contains most of these:

Great Britain: National Institute for Research in Dairying, Shinfield, nr. Reading. Hannah Dairy Research Institute, Kirkhill, Ayr.
Australia: Dairy Products Research Station, Lorimer Street, Fishermen's Bend, Melbourne.
New Zealand: Dairy Research Institute (N.Z.), P.O. Box 602, Palmerston North.
India: Indian Dairy Research Institute, Hosur Road, Bangalore.
Norway: State Dairy Research Institute, Vollebekk.
Denmark: State Dairy Research Institute, Hillerød.
Sweden. State Dairy Research Institute, Alnarp.
Germany: Dairy Research Institute, Kiel. South German Research Institute for Dairying, Weihenstephan.
Austria: Dairy Research Institute, Wolfpassing.
Switzerland: Federal Institute of Dairy Industry and Bacteriology, Lieberfeld, Berne.
Belgium: State Dairy Research Station, Ghent.
Holland: State Dairy Research Institute, Wageningen.
Hungary: Hungarian Dairy Experiment Institute, Mosonmagyaróvár.
U.S.S.R.: Siberian Institute for Research in Dairying, Novosibirsk. Dairy Institute, Vologda.
U.S.A.: Bureau of Dairy Industry, United States Department of Agriculture, Washington, D.C. Much dairy research is also carried out in the laboratories and on the farms of a large number of State Universities and agricultural experiment stations.

The Scope of Dairy Research. Most science departments in a university deal with one discipline only—*e.g.* botany, physics, bacteriology, biochemistry, genetics. In dairy research, however, any or all of the disciplines just mentioned, and others beside, have to be brought to bear on the multifarious problems of the widely ramifying dairy industry. Scientifically, therefore, as Dampier stated, the scope of dairy research is inevitably very broad, and any modern organisation which hopes to be able to handle a reasonable fraction of the research problems of the industry must bring together in the closest collaboration experts in several different scientific fields. In dealing with the breeding, feeding and management problems on the dairy farm, not forgetting those concerned with milking technique, the geneticist, the physiologist, the biochemist, the botanist, the chemist, the bacteriologist, the animal nutritionist, the veterinary man and the engineer are all from time to time required. Many of the serious problems arising in relation to milk production involve the work of a small team, and not infrequently require the acquisition of quite new knowledge before a firm basis for future farm practice can be established. For example, it is becoming more and more important in Britain to improve the yield per cow and per acre of milk nutrients. The factors controlling milk yield and quality are known to be highly complex; the genetic make-up of the cow, and her physiological efficiency in relation to her environmental conditions, act and react with one another in ways at present only partially understood. There is known to have been a slow fall in average milk quality over the last 20 or more years; there is said to be evidence of lowered bovine fertility in certain districts; metabolic disturbances such as bloat, grass tetany and milk fever, which sometimes lead to disaster, are far from infrequent. Problems such as these require attention from a *team* of specialists, each with different training. The slowness with which effective knowledge in these fields has hitherto been acquired is probably due in part to the fact that this plain research necessity is only now being realised.

The study of reproduction and lactation in the cow, on which processes the industry is essentially based, is the legitimate field of the animal physiologist and biochemist, and as the result of their work remarkable developments (for example, artificial insemination, virgin lactation, the use of deep-frozen semen) have arisen in the fairly recent past, and there is little doubt that the near future will see advances of no less importance and scientific interest.

Further, the modern dairy farm is becoming more and more mechanised. Milking machines, refrigeration plants, apparatus for steam sterilisation of utensils (to exclude for the moment the various machines and appliances used for ordinary farm purposes and for the preparation of food for stock), call for research on the interlinked problems of design, performance and durability under actual dairy farm conditions. Much of this research requires close collaboration between the engineer and the bacteriologist, and in respect of milking machines the physiological and veterinary aspects must also be closely considered.

In milk processing and distribution also, progress largely depends on constant collaboration between the bacteriologist and the engineer, with the nutritionist keeping a close eye on the possible effects of any new method of treatment of milk on the nutritive value of the product. A clear example of the results that can follow in a relatively short time when scientific and technological research are combined in an attack on a central problem of the industry is the mechanical, bacteriological and economic efficiency of modern high-temperature short-time pasteurisation. The central problem of the milk distributing industry is to provide the consumer with a supply of safe milk of consistently good keeping quality and unimpaired nutritive value with a very low expenditure of economic resources. Dairy research has solved this problem, though this is not to say that technically and economically satisfactory solutions other than the H.T.-S.T. process may not at some future time be found.

As regards the manufacture of dairy products—in Britain mainly butter, cheese, dried and condensed milks, and also ice cream—we are also confronted with problems of bacteriological and chemical engineering. In the case of butter and cheesemaking, where micro-organisms are employed as an essential tool in the manufacturing process, recent research has solved some awkward problems by the application of scientific principles to factory methods, for example, the control of slow starters, which required for its solution both skilled technological investigation in the factory and the careful study in the laboratory of the ultramicroscopic bacteriophages which have been shown by dairy research workers to be responsible for starter failure. Another example of close collaboration between the bacteriologist and the chemist is shown in recent work on ripening in relation to flavour in cheese where the joint work of the dairy bacteriologist and the specialist in chromatography is throwing light in this previously obscure field. In research on methods for the assessment of quality in cheese and butter, both physical and psychological techniques are being jointly employed, and have stimulated the development of the new science of psychorheology.

Aldous Huxley has suggested that if any group of facts is pulled on sufficiently hard, the whole of science may be brought out with it. Somewhat similarly, if the already wide field of dairy research is extended with too implacable a logic, it will become almost co-terminous with the whole of scientific research. A vast armamentarium of costly apparatus and highly specialised method, from infra-red spectrophotometry to the use of radio-active isotopes, is already and of necessity employed in dairy research institutes. But there must clearly be some practical limit as to what can, at any given time, be regarded as a fit subject for research in any given dairy research organisation. In Britain, the present arbitrary but convenient division allocates strictly veterinary research on the dairy cow to other than dairy research organisations. Whilst dairy research can and must concern itself with diseases which affect milk quality (mainly those diseases coming under the generic heading of mastitis) which veterinary science must also investigate (thus causing an inevitable but quite stimulating overlap), work on those diseases of the cow which do *not* immediately affect the udder can, for present purposes, be excluded from dairy research.

For convenience and general efficiency, the detailed study of the genetics and breeding of dairy cattle is, in Britain at least, relegated to a separate organisation from those engaged in dairy research. This organisation, the Animal Breeding and Genetics Research Organisation in Edinburgh, of course, keeps in close touch with dairy scientists. Again, the study of the economics of the dairy farm or the dairy industry, which, from the standpoint of the objective dairy scientist, abuts rather dangerously on the field of opinion and trade policy, can probably be better tackled by an organisation dealing mainly with the specialised discipline of economics, though collaboration with the well-informed student of dairy husbandry or dairy technology is of obvious importance. The breeding of improved grasses and of other fodder plants which can be grown on farms, is obviously of first importance to the dairy husbandman, and of outstanding importance today, when for most countries the importation of animal feeding stuffs from sources that provided them in large quantities before the world war has such a dubious future. Research on such questions is conveniently left in the hands of applied botanists in specialised research institutes and universities; where dairy research is directly concerned in this field is in the evaluation of the newly-bred varieties or strains in relation to milk production and also in the working out of efficient methods for grazing and feeding management which allow of high yield and quality in milk, while avoiding metabolic disturbance to the cow.

Contact between Research and the Dairy Industry. One of the main problems of an institute, or of a specialist worker, in the field of dairy research is neither a strictly scientific nor a technological one, though a scientific approach may be needed to solve it. It is the problem of finding out what are the most serious questions, which are not always the most fashionable questions, requiring investigation, putting them in order of priority of importance, and dealing with first things first. In practice, a proportion of the research workers in any reasonably well-organised dairy research institute must automatically maintain close and direct contact with at least certain sides of the industry. In Britain, the active Society of Dairy Technology, concerned mainly, though not exclusively, with milk utilisation, and the extensive National Agricultural Advisory Service, concerned *inter alia* with problems of milk production, have very useful liaison functions, in calling the attention of research workers in dairy science to difficulties which may not even be recognised by the milk producer or distributor as being other than quite normal conditions, but which are capable of solution if a solution be sought with scientific skill and pertinacity. Of the existing major problems in the dairy industry, some are politico-economic, some are labour and incentive problems, some are concerned with producer or consumer " psychology " or prejudices. Whilst these are perhaps outside the strict scope of dairy research, it is beyond doubt that in many of them there is an unsolved scientific or technological aspect. For example, the relatively low consumption of milk per head in certain parts of Britain, labour difficulties caused by the seasonal character of cheese- and butter-making, the tardiness of the application, by certain groups in the industry, of improved methods of proved value—all these are present problems to which the scientific method can at least in part be applied.

The Value of Dairy Research. Can the value of research to the dairy industry be in any way assessed? A sum of the order of £250,000, mostly from public funds, is spent on dairy research each year in Great Britain. While this represents considerably less than 0·1 per cent. of the value of the annual turnover of milk in Great Britain, it is nevertheless no negligible sum. What return for this national expenditure is there to the milk producer, the milk distributor or the milk consumer, or to the general economy of the nation?

On broad lines it is not unfair to say that most of the progress and development of the dairy industry in Great Britain over the past 50 or 60 years from the very primitive and wasteful methods of the eighteen-nineties to those of today, with increased yields of milk per cow and per acre, greatly improved hygienic, keeping and organoleptic quality of the product, increased consumption of safe milk per head of the population with its corollaries of improved national health, especially amongst the younger members of the population, and increased prosperity of dairy farmers and the milk distributing industry, is very largely due to dairy research of one kind or another. Some of this research, it is true, has been conducted abroad, but a large proportion of it has been carried out in Britain, not only in official dairy research stations but in several other laboratories and in scores of dairies. Its value cannot be exactly assessed in pounds, shillings and pence, but even in this currency, it must amount to many millions of pounds annually. Modern technique of milk handling, founded on dairy bacteriological research, results today in no more than quite minor losses of milk as a result of souring, whilst only 25 years ago large quantities were regularly lost every summer from this cause. Production of milk in Great Britain has gone up between 1913 and 1953 by over 50 per cent., average consumption per head per day of liquid milk has risen from 0·25 pint to 0·68 pint. Methods of processing, distribution and manufacture, largely dependent on research for their progress, have steadily improved. The percentage pasteurised of the milk supply of many of our great cities is now well over 90 per cent. Without using the findings of applied research, no milk distributing firm could remain for long in business—one can imagine the chances which a firm, using the methods of 1900, or even those of 1925, would have in the industry today.

The increased application in the industry of the knowledge gained by dairy research, accentuates the need for improvement both in general and in technological education of most of those entering or already engaged in the industry. This means not merely the acquisition by new entrants of up-to-date technological knowledge of dairy farming or milk handling and manufacture, but a system of regular refresher courses thereafter and close touch with publications dealing with dairy science, so that new knowledge obtained by research may be incorporated into dairy practice or used to solve practical difficulties with the minimum of delay.

The education and training of those entering dairy research will not be dealt with in this article. It is sufficient to say that increasing technological development in any industry goes hand in hand with increasing specialisation in the research associated with that industry and necessitates, whether we like it or not, intensive training along specialised lines, for would-be entrants to the field of dairy research. For established research workers, it means a never-ending effort to keep abreast, through the widely various professional, technological and scientific societies and their publications, with new knowledge and fresh ideas alike in their specialised field of research and in the neighbouring " pure " sciences.

Publication of Dairy Research Findings. For a list of journals dealing with dairy science *see* Literature of Dairy Science. Amongst the main channels for publication of dairy research findings are *The Journal of Dairy Research, The Journal of Dairy Science, Le Lait, The Journal of the Society of Dairy Technology, Indian Journal of Dairy Science, Netherlands Milk and Dairy Journal, Journal of Milk and Food Technology, and Die Milchwissenschaft.* A large number of other journals publish from time to time articles dealing with original research in dairy science.

RESEARCH INSTITUTES, ETC., IN GREAT BRITAIN.

1. Agricultural Advisory Department, The University, Bristol.
2. Agricultural Advisory Department, University College of South Wales and Monmouthshire, University of Wales, Cardiff.
3. Agricultural Advisory Department, The University, Manchester.
4. Agricultural Buildings, University College of Wales, University of Wales, Aberystwyth.
5. Agricultural Economics Research Institute, Oxford.
6. Animal Diseases Research Association, Moredun, Edinburgh.
7. Animal Nutrition Institute, Cambridge.
8. British Baking Research Association, Baking Industries Research Station, Chorleywood, Herts.
9. British Coke Research Association, 74 Grosvenor Street, London, W. 1.
10. British Electrical and Allied Industries Research Association, 5 Wadsworth Road, Greenford, Middlesex.
11. British Food Manufacturing Industries Research Association, Randalls Road, Leatherhead, Surrey.
12. British Gelatine and Glue Research Association, 2A Dalmeny Avenue, Holloway, London, N. 7.
13. British Hydromechanics Research Association, Eastern Industrial Estate, Harlow, Essex.
14. British Leather Manufacturers' Research Association, Milton Park, Egham, Surrey.
15. British Scientific Instrument Research Association, SIRA, Southill, Elmstead Woods, Chislehurst, Kent.
16. Building Research Station, Garston, Nr. Watford, Herts.
17. Bureau of Agricultural Parasitology, Institute of Agricultural Parasitology, St. Albans.
18. Bureau of Animal Breeding and Genetics, King's Buildings, Edinburgh.

19. Bureau of Animal Health, Veterinary Laboratory, Weybridge.

20. Bureau of Animal Nutrition, Rowett Research Institute, Aberdeen.

21. Bureau of Animal Population, Oxford.

22. Bureau of Dairy Science, National Institute for Research in Dairying, Reading.

23. Bureau of Forestry, 39 Museum Road, Oxford.

24. Bureau of Horticulture and Plantation Crops, East Malling Research Station, East Malling, Kent.

25. Bureau of Pastures and Forage Crops, University College of North Wales, Aberystwyth.

26. Bureau of Plant Breeding and Genetics, School of Agriculture, Cambridge.

27. Bureau of Soil Science, Rothamsted Experimental Station, Herts.

28. Chemical Research Laboratory, Teddington, Middlesex.

29. Cod-liver Oil (Poultry) Standardisation Laboratory, National Institute for Research in Dairying, Shinfield, nr. Reading,

30. Department of Agriculture, King's College, Newcastle-on-Tyne.

31. Department of Agriculture, The University, Leeds.

32. Department of Agriculture and Horticulture, The University, Reading.

33. Department of Biochemistry, Cambridge University.

34. Department of Botany, Imperial College of Science and Technology, London, S.W. 7.

35. Department of Botany, University of Birmingham.

36. Department of Pathology, University of Aberdeen.

37. Department of Veterinary Science, The University of Liverpool.

38. East Malling Research Station, Kent.

39. Edinburgh and East of Scotland College of Agriculture, Edinburgh.

40. Experimental and Research Station, Cheshunt, Herts.

41. Experimental Research Station (Veterinary) of the Agricultural Research Council, Compton, Berks.

42. Fire Research Organization, Fire Research Station, Boreham Wood, Elstree, Herts.

43. Food Investigation Board, 20A Regent Street, Cambridge.

44. Foot and Mouth Disease Research Station, Pirbright, Surrey.

45. Forestry Products Research Station, Princes Risborough.

46. Fuel Research Station, East Greenwich, London, S.E. 10.

47. Grassland Improvement Station, Dodwell-Drayton, Warwickshire.

48. Hannah Dairy Research Institute, Ayrshire.

49. Harper Adams Agricultural College, Newport, Salop.

50. Horticultural Research Station, Cambridge.

51. Institute of Agricultural Parasitology, St. Albans, Herts.

52. Institute of Animal Genetics, Edinburgh.

53. Institute of Animal Pathology, Cambridge.

54. Institute of Entomology, British Museum (Natural History), London, S.W. 7.

55. John Innes Horticultural Institution (Fruit Department), Merton, Surrey.

56. Long Ashton Research Station, Bristol.

57. Low Temperature Research Station, Cambridge.

58. Macaulay Institute for Soil Research, Aberdeen.

59. Mechanical Engineering Research Laboratory, East Kilbride, Glasgow, Scotland.

60. Mycological Institute, Ferry Lane, Kew, Surrey.

61. National Institute of Agricultural Botany, Huntingdon Road, Cambridge.

62. National Institute of Agricultural Engineering, Silsoe, Beds.

63. National Institute of Poultry Husbandry, Harper Adams Agricultural College, Newport, Salop.

64. National Institute for Research in Dairying, Shinfield, Reading.

65. National Physical Laboratory, Teddington, Middlesex.
66. North of Scotland College of Agriculture, Aberdeen.
67. Nottingham University, Dept. of Agriculture.
68. Pest Infestation Laboratory, Slough, Bucks.
69. Plant Breeding Institute, Cambridge.
70. Plant Pathological Laboratory, Harpenden, Herts.
71. Plant Virus Research Station, Cambridge.
72. Research Institute in Animal Pathology, Royal Veterinary College, Streatley, Berks.
73. Research Institute of Plant Physiology, Imperial College of Science and Technology, London.
74. Rothamsted Experimental Station, Harpenden, Herts.
75. Rowett Research Institute, Aberdeen.
76. Royal (Dick) Veterinary College, Edinburgh.
77. School of Agriculture, Cambridge University.
78. School of Agriculture, University College of North Wales, University of Wales, Bangor.
79. Scottish Society for Research in Plant Breeding, Edinburgh.
80. Seale-Hayne Agricultural College, Newton Abbot, Devon.
81. Strangeways Research Laboratory, Mills Road, Cambridge.
82. Unit of Animal Physiology of the Agricultural Research Council, Cambridge.
83. Unit of Soil Enzyme Chemistry of the Agricultural Research Council, Rothamsted, Herts.
84. Water Pollution Research Laboratory, 103 Langley Road, Watford, Herts.
85. Wellcome Physiological Research Laboratories, Beckenham.
86. Welsh Plant Breeding Station, Aberystwyth.
87. West of Scotland Agricultural College, Glasgow.
88. Wye College, Kent.
89. Veterinary Laboratory, Weybridge, Surrey.
90. Zoology Department, Cambridge University.

See Agricultural Colleges.

RESILIENCE. Elasticity. *See* Rheology.

RESISTANCE OF BACTERIA. *See* Classification; Coliforms; Lactic acid bacteria; Refrigeration; Stability; Thermoduric bacteria; Thermophilic bacteria.

RESPIRATION. Respiration may be regarded as the oxidation of tissue matter by free oxygen or oxygen already combined with other substances, *e.g.* as in methylene blue or resazurin. Sugars and fats are the chief source of energy for most organisms and their combustion or burning by oxygen forms the most efficient method of providing the organism with energy. Carbon dioxide and water are formed as the end products of respiration:

$$\underset{\text{sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

In all media such as milk, sewage, water, etc., in which micro-organisms are living, there is an equilibrium between the rate of diffusion of oxygen into the liquid and the rate of using up the dissolved oxygen by respiration. Only when the number of bacteria is so great that respiration uses up the oxygen faster than it can enter from the air, can dyes such as methylene blue be reduced. Microbial respiration is also of the greatest importance in controlling types of bacteria predominating under various conditions and is also a major factor in such taints as oiliness (p. 313).

Fermentation (p. 470) is a break down of sugars, etc., in the *absence* of air; respiration the burning of these sugars, etc., by the oxygen of the air.

Refs : Stephenson ; Summer and Somers.

RETAIL DAIRYING. The point at which retailing commences in milk distribution is where the filled and sealed bottles of milk leave the filling machine. This is literally so where the retailer is selling the product from his own processing (pasteurising or sterilising) plant. If the milk is purchased already processed and/or bottled, then the retailing commences at the time of delivery from the wholesaler, which is equivalent to delivery from off the filling machine.

Where the dairyman uses only the one premises the first stage in retail distribution is for the bottled milk, packed into crates of standard size, to be stacked in a cold store to await delivery to consumers by the roundsman. This usually occurs on the following morning, the normal practice being for the day's delivery to be effected from the previous day's processing, while the current day's intake from farms is being handled and processed ready for the following day's delivery. In the case of a multiple organisation, that is, where one processing and bottling plant serves more than its attached distribution premises, the milk is transported directly from the fillers to the cold stores located at each distribution premises. Thus, whatever form the business organisation takes, suitable cold storage is required at the point immediately before the milk starts on its final street journey to the homes of consumers.

At the time of bottling, the (pasteurised) milk has already been cooled to a temperature of near 40° F. It is very undesirable to allow any appreciable rise in its temperature before finally being placed on the roundsman's vehicle. Hence, good practice demands that the time which elapses between leaving the filler and getting into the distribution cold room shall be the least possible. Should the distance between plant and distribution cold room be more than a few miles, say half an hour's journey, then the transport vehicles used should be of the enclosed type to minimise atmospheric re-heating, particularly in times of summer temperatures.

These distribution cold stores may be either of two types, the built-in or the portable. The former consists of a brick chamber suitably lined with cork insulating material and faced with a smooth impervious coating having all angles rounded in order to give a completely hygienic interior. In the latter type, a timber framing with wooden outer skin takes the place of brick. The hygienic lining is usually of glazed asbestos or similar material, and the whole can be dismantled into its sides, top and floor framing with only the sacrifice of the granolithic floor when it is desired to move and re-site the store. On the other hand, a built-in store is a permanent thing, and is usually incorporated as part of the main buildings of the distribution centre. It will be apparent that the choice of type depends on the daily throughput. Unless there are some suitably placed existing walls capable of being readily embodied into a built-in store, then a daily throughput of about 350 gal. represents the maximum for which sectioned (or portable) cold stores are an economic capital investment. But in the case of a multiple business with a number of distribution branches in the process of building up and for which the ultimate cold store capacity cannot be estimated, or for which it would not be economic to install built-in stores at the outset, there is an attraction in making use of a sectional unit standardised as to size, say of 500 cu. ft. capacity. At a growing branch the requisite cold store capacity can be built up by the addition of a unit as necessary. When conditions of maximum throughput that can conveniently be handled at the branch are reached, a permanent cold store can be substituted and the standard unit(s) can be transferred elsewhere to use again in the same way. Moreover, a number of standardised units provides considerable attraction from the maintenance point of view, as a single motor-driven condensing unit will provide complete spares for any store.

Whichever the type of store selected, the method of cooling the chamber is important. Undoubtedly the most effective method is by means of circulating air forced by fan over the coils of the evaporator operated by the condensing unit. This system tends to maintain reasonably dry conditions in the chamber, and condensed moisture being effectively trapped (by frosting) on the evaporator and subsequently easily drained to the outside on de-frosting. Circulated air is much quicker in operation than the older system of circulating chilled brine through pipes attached to the ceiling, which is now rather outmoded. The slight loss of reserve capacity given by the brine in the pipes is far outweighed by the faster temperature reduction effected by forced air circulation.

The temperature of distribution cold stores should be maintained at about 40° F., and for effective and economical working this should be achieved by automatic thermostatic control of the condensing unit, not forgetting to have a good quality thermometer, properly protected from breakage, fitted in the chamber to see at all times that the correct temperature is held.

The most arduous task, from the point of view of physical exertion, in retail milk distribution is the handling of crates of full milk bottles. In spite of modern mechanisation, quite an amount of this must be done by hand. Most of this occurs at the distribution cold store, and it is remarkable how much can be eliminated by installing the store on a platform or " bank ", the top of which is at approximately the level of the floors of the vehicles used for delivering thereto. When this is done, stacks of full crates can be " skidded " off the vehicle to their place in the cold room. Conversely, when retail delivery vehicles are being loaded from the cold room, the crates, having been skidded out on to the platform, require the minimum of vertical movement (*i.e.* lifting) to put them in their place on the vehicle. Building up a platform as described is not cheap, but it pays well in reduced handling breakages, better labour conditions and reduced risk of physical hurt to staff.

Before starting the milk on its final delivery journey, something should be said about the clerical supervision of the quantities passing through the distribution cold store. Experience shows that it is here where one of the largest contributions to the general " wastage " can be made. More so is this the case when the bottling and distribution are from the same premises. It is most desirable that, for accurate supervision and to minimise losses due to " unaccounted for " quantities of milk, there should be as complete separation between the bottling section and retail delivery as possible. Where separate premises are involved this is physically, as well as theoretically, possible. However, whatever the circumstances, the quantity of milk delivered to the distribution cold store should be booked. Similarly, the amount taken by every round, less credits for any returns, should be properly recorded. A simple daily account, made up of the items initial stock, amount received during day, net amount issued, closing stock and waste, is well worth preparing as it provides a close check on undue losses due to careless handling in and out of the store. In any case, the record of daily issues provides the basis for checking roundsmen's accounts, and is therefore vital. A single daily sheet, suitably arranged and printed, will serve to provide all the information mentioned above.

From the distribution cold store the milk goes on to vehicles for delivery to consumers. There are several types of vehicles in use today, depending on the extent and nature of the area covered. The first, and cheapest from the point of view of first cost and operating cost, is the hand pram. At one time these were specially fitted internally with tray type bottle crates to which the milk had to be transferred from the dairy crates; but with steadily rising labour costs, this system is found to be too wasteful in time with little or no advantage to compensate. The present day hand pram is usually designed with internal racks into which the dairy crates are placed directly, so obviating the handling of the individual bottle until the household of the consumer is reached.

Under the impact of the 1939-45 War, shortage of man power and other measures for economy of effort, particularly the scheme of rationalisation, focused attention on the necessity for very appreciable increases in the amount of milk carried per vehicle. Owing to rationalisation, it became possible for a roundsman to distribute, generally over a shorter distance, a much greater quantity of milk in the same time. Very soon it was found that physical ability to man-handle the pram was limiting the amount of milk capable of being distributed per round. Consequently, attention was directed to electrically propelled prams of the type known as pedestrian controlled. With these, electricity moves the load while the roundsman walks freely, only having to guide the vehicle. With the use of this type of vehicle in densely populated areas surrounding the distribution point, it is often possible for a roundsman to return for a second, and even third, load, all of which, under current conditions, can be distributed to consumers in a normal working time.

Where rounds are somewhat farther away from the distribution point and commence, say, three or more miles therefrom, a vehicle of somewhat larger capacity and greater speed is required. The time taken in reaching the first customer is unremunerative, as would be the time taken in returning for additional loads. Up to recent years horse-drawn vans have usually catered for these requirements, but now the larger, four-wheeled, electrically propelled van is fast becoming an accepted competitor. Although more expensive in first cost, this type of vehicle does not require special stabling, attendance and feeding for its motive power, and has some attractiveness in its silence of operation. Moreover, with its instantaneous availability, rapid acceleration and daily range of up to 15 miles, it is very suitable for the medium long type of round, particularly as it also has the merit of requiring no physical exertion in operation by the roundsman additional to that required for the servicing of customers.

The maintenance of these electrically operated vehicles is comparatively simple as the number of moving parts is an absolute minimum. Moreover, modern charging equipment for use with A.C. supplies is such as to make the process of re-charging the batteries during non-working hours almost a fool-proof operation. The metal rectifier type of charger is practically standard. It is always worth having a special relay fitted to these chargers, as this automatically controls the final " gassing " period for the batteries and also stops the charging at the end of that set time, that is, when the battery is properly and fully charged. Damage to batteries by incorrect or over charging is thereby avoided. Further, immediately roundsmen arrive to commence the day's work the vehicles are instantly available and fully charged, it only being necessary to disconnect the charging plug.

It will be apparent from the foregoing that the use of petrol-driven vehicles is decreasing in city and urban areas which are fairly densely populated. But in the rural areas, where the number of consumers per mile of road is very much less, the distance travelled on a single round is beyond the range of the electric vehicle. In fact, in these areas the time taken limits the amount of milk delivered per day. It is here that the light, 5 cwt. to 10 cwt. petrol-driven van finds its application. Its range is, of course, ample, and its higher speed on the longer intervals between customers helps to reduce the unremunerative roundsman's time. But maintenance worries are much greater than in the case of electrics, and starting difficulties in cold weather can seriously disturb the orderly distribution routine.

The distribution of milk is the only trade which demands, and provides, a call at a household on every day of the year. Newspapers do have a few days of non-publication. It is, therefore, not surprising that the dairy roundsman becomes quite a personality with the households at which he calls. First and foremost, because of the all-weather and continuous nature of the job, a roundsman must be physically fit. Then he must be of pleasing personality in order to cope with the many different temperaments of his customers he will meet each day. Finally, he must be good and accurate with figures, and no poor hand at clerical work, of which he has quite a lot to perform each day.

Running right through the actual chain of distribution, from the milk in the cold store till it is delivered to the customer, it is essential that there should be a satisfactory system of stock control. Every drop of milk issued (less any returns) from store to roundsmen, must be charged to the particular round. Similarly, customers must be properly charged with all milk they purchase. The total of customer bookings each day on each round should be checked against the net quantity issued from store. Any difference indicates short or over bookings against customers. The former represents a direct loss to the dairymen, and is usually counteracted by charging to the roundsman personally. The latter will ultimately cause complaint by customers, with consequent loss of goodwill, and will not usually be paid. So it will be seen that a rigid system of checking not only acts as a deterrent against physical losses, but assists in keeping the valuable goodwill of customers.

There are various bookkeeping methods used in connection with milk distribution. The type depends to some extent on the size of the individual business. Where there are only one or two rounds to a business, it is possible to use the roundsman's book as the permanent record of all transactions with customers. This method has the disadvantage that the immediate past records are away from headquarters every day and, as the rounds-book is used in all weathers, there is always considerable risk of spoiling. For that reason, it is more usual for medium-sized businesses to use a ledger system. The ledgers are retained at the distribution headquarters and the entries in the roundsman's book are transferred thereto at the end of each day. The checking referred to above is then conveniently carried out on the following day while the roundsmen are out. Again, time is available to scrutinise individual customer accounts to ascertain if any abnormal amount of credit is being taken, which can be corrected by appropriate action. Thus is the item of loss due to bad debts minimised.

When only one grade of milk is retailed and the booking is in pints, the above ledger system can be quite efficiently operated, that is, the indoor clerical staff required is not excessive. But the considerable multiplication of grades (under various Special Designations) in recent years makes booking by price almost a necessity. The figure work therefore becomes more complicated and the overhead expenditure on clerical labour becomes a matter for serious attention. As a result of this, the so-called " mechanical booking " system is finding extending use in milk distribution. With this the roundsman's book is specially arranged so that each page is confined to one customer's account, and covers a period of from 4 to 10 weeks. Milk and other goods are charged in total cash in one column, any payments received are entered in the next column, and a third column provides the daily running balance on the account. In the clerical office the value of the milk and goods charged to the roundsman is known (in the way previously described). This, added to the total balance outstanding previously on his book, gives the total to be accounted for, and should be equal to the amount of cash paid in plus the total final balances on his book. Hence, the totalling of the customers' balances in the roundsman's book is the major operation in applying the necessary checks, and this is a procedure which is ideally suited for the employment of adding machines. The type of machine used is that which prints the items on a paper strip. If every page of the book is added in without exception, zero balances being added as nothing, then the strips become an office record of the state of each customer's account at the time of each checking. This system is very much faster in operation and requires much less clerical labour, advantages which outweigh the disadvantage of loss of detail in individual accounts.

The final link in the chain of retail milk distribution is, of course, the consumer. But there is some difficulty in commenting on this because the whole relationship between dairymen and their customers is, just now, in a state of complete uncertainty. Owing to the Second Great War it became necessary for consumers to register with their milk suppliers and, except in exceptional circumstances, the two thus became tied together. Again, the scheme of rationalisation, introduced as a war-time measure of economy, separated many long-standing, satisfied consumers from the suppliers of their choice and tied them to other suppliers. Moreover, through distributors being zoned into areas, the possibility of competitive private trade supplies being available as before the war has been removed. It is expected that the registration of customers will cease in due course, although price control, and therefore control of dairymen's margins, may continue for some time. The set-up for milk distribution from the consumer's angle in the near future cannot be forecast in any way. But it is reasonable to anticipate that the rather extravagant pre-war methods of distribution, resulting largely from dis-orderly competition, will not return. Fortunately, war time expedients applied to milk distribution will not be largely wasted. The necessity to utilise to the full home-produced food supplies, of which milk is probably the most important, drew considerable attention to the question of keeping quality of milk, and great strides were made in improving it. The consumer was generally forced to have delivery only once per day, and therefore had to learn to keep milk for use for twenty-four hours. Similarly, dairymen had to improve their milk so that it would remain usable for that time. The measures taken to this end will be found described in other sections.

Under recent legislation, the compulsory pasteurisation of milk other than that from tubercle free herds is envisaged, and this will undoubtedly lead to the concentration of milk distribution into larger units with corresponding reduction in competitive choice available to the consumer. This again is a factor which makes difficult any forecast of the reactions and requirements of consumers generally. Today, the consumer is not a free agent in the choice of milk supplies and the prospects of becoming so are very indefinite. There is, therefore, no way of ascertaining and describing the general requirements of the public regarding the ways and means by which milk is retailed. *See* Bacteriological grading; Bottles; Cartons; Costings; Legal aspects; Milk marketing; Transport.

Ref.: Williams; Compton and Davies (1953), *IDC*, **3**, 1447; Nell, 1500.

RETICULUM. The second chamber of the ruminant's stomach. *See* Digestion.

REYNOLD'S NUMBER. *See* Flow of liquids.

rH. A convenient shorthand code for indicating the reducing conditions in a system, *e.g.* bacterial culture, milk, cheese, etc., independently of pH. It is related to E_h (the true electrode potential) and pH by the formula

$$r\text{H} = \frac{E_h}{0{\cdot}03} + 2p\text{H}$$

See Acidity; E_h; Oxidation-reduction potential; pH.

RHEOLOGY. Although the name of this branch of physics is derived from a Greek word meaning " flow ", rheology is defined as the science of the deformation and flow of matter, and thus includes elastic deformations. Moreover, such studies as hydrodynamics, aerodynamics, and large sections of metallurgy fall, strictly speaking, within the field of rheology but are not, in practice, generally included in the term.

It so happens that there are two relatively simple types of behaviour which are approximately followed by quite a number of important materials. Liquids (*q.v.*), like water, milk and all but the heaviest oils, when submitted to a steady pressure, flow at a steady rate and, if the pressure is changed (unless it be sufficiently high to produce turbulence), the rate of flow will likewise change in proportion. The pressure divided by the rate of flow is thus a constant for any given sample provided temperature does not change, and this constant property is known as " viscosity " (*q.v.*).

Solids, such as metals, do not normally flow appreciably except at high temperatures or pressures, but deform to an extent proportional to the pressure applied, the deformation disappearing immediately if the pressure is removed. This is known as elastic behaviour, and the constant obtained by dividing the pressure by the amount of deformation (as a proportion of the original size of the test piece) is known as the " Compression Modulus ".

Most elastic materials change their volume as well as their shape when forces are applied to them and the ratio of force to change of volume is known as the Bulk Modulus.

Provided the material has the same elastic properties in all directions (isotropic material) only these two elastic constants are needed fully to describe its behaviour; though other moduli, derived directly from them, are often used: *e.g.* Young's modulus, which is the elastic modulus of extension, the Rigidity modulus for shears, and Poisson's ratio which is the ratio of the sideways expansion to the downward compression in, for example, the compression of a cylinder.

For such materials as wood, which has " grain ", 9 elastic constants are required; for the most complicated cases of anisotropy (difference of behaviour in different directions) 21 constants would be needed.

Resilience (*q.v.*), which is measured from the height to which a ball dropped on to a material will rebound, and indicates the amount of elastic energy which a body can store, is also a useful concept, but has not been much used in the dairy industry.

Milk is almost a " true " fluid: *i.e.* its viscosity as above defined is very nearly independent of pressure. Very hard cheese is, for small pressures, almost an elastic solid, though it is seldom isotropic. But the great majority of dairy products—cream, butter, condensed milk, processed cheese, cheese curd during manufacture and most finished cheese—have neither constant viscosities nor elastic moduli.

The relationships between the applied forces and the deformations produced and their changes with time are important for all these materials, but the problem of their formulation is extremely complex.

With cream, for example, the " body " is often taken as an indication of richness or quality; but if we measure the viscosity of cream, we find that not only is the rate of flow not proportional to the applied pressure, but that there is not even a steady rate of flow for any given steady pressure. The cream is softened by the working and gets firmer again when left to stand (" False body " or Thixotropy).

Some butters spread more readily than others; but, if we try to describe " spreadability " by means of a single figure, we shall not even get the samples into the same order, if the tests are carried out under slightly different experimental conditions.

Sweetened condensed milk is apt to become gelatinous when kept for too long, but part at least of the " body " which it develops is false and disappears on stirring. If the protein has been affected in certain ways, the milk will climb up a vertical rod rotated in it, a very complex phenomenon whose explanation is still a matter of controversy between rheologists.

The " body " of cheese is generally regarded as of such importance that some 40 per cent. of the marks in competitions are allocated to this property and to texture. (The latter term is generally confined to what can be seen and the former to what can be felt.) Cheese which has poor body is apt to undergo undesirable bacteriological and chemical changes.

Since butter and cheese do not have constant ratios of applied pressure either to extent or to rate of deformation, the problem arises as to how to describe their rheological behaviour.

Earlier workers very naturally followed the procedures of classical physics, and assumed that such complex materials either consisted of mixtures of simple elastic and viscous elements or at least behaved as if they consisted of them.

Let us follow James Clerk Maxwell (1868), for example, and picture an elastic spring attached to a piston sliding in a cylinder filled with oil. When this model is suddenly stretched, there is an immediate elastic extension of the spring, and if this tension is then released, the spring recovers and the whole model resumes its original condition: *i.e.* behaves elastically. If the tension is maintained, however, the piston gradually slides through the oil in the cylinder, thus allowing the spring to relax, so that when the tension is finally released, only part of the total deformation is recovered. The viscosity of the oil defines the rate of dissipation of the force for any given tension in the spring, and the elastic modulus of the spring defines the extent of the original total deformation. Dividing the former by the latter, we get the time taken for the tension in the model to relax to a certain proportion $\left(\frac{1}{e}\right.$, where e is what is called the base of natural logarithms $\left. 2{\cdot}718\right)$ of its initial value. This is called the " relaxation time ".

It is clear that the softer the spring and the thicker the oil, the greater will be the deformation recovered when the tension is released. Hence a high relaxation time is generally associated with " springiness ".

Unfortunately the behaviour of cheese cannot be described in terms of a single relaxation time: if a model is to be adequate, it must contain many springs and viscous elements linked both in series and in parallel. Alternatively, if we attempt to describe the behaviour of cheese in terms of the combined action of one elastic and one viscous element, neither the elastic modulus nor the viscosity will be constant and, far from being able to describe the body of each cheese by two constants, we shall end by having two packets of graphs!

Two alternative methods have been tried. The former describes behaviour in terms of " properties " which lie between viscosity and elasticity so that for each cheese, at least two figures must be quoted: first a quantity analogous to the magnitude of an elastic modulus or a viscosity, and secondly a number expressing how far the cheese behaves more like a liquid than like a solid (*e.g.* 1·0 would indicate a viscous liquid and 0 an elastic solid: for an ordinary ripe Cheddar cheese, the value would normally be about 0·2). Most British hard-pressed cheese can be classified with respect to body in this way.

The second method is to submit the cheese to a battery of empirical tests, such as are often used for other materials such as bitumen, plastics, rubber, etc., and then to study the relationship between the scores in the different tests by a statistical method known as Factor Analysis. In many cases, when large numbers of samples have been examined, the relationships between the scores in the different tests are found to assume a fairly regular pattern. When this is so, the number of tests needed to specify the cheese may be reduced or at least the number of magnitudes needed to describe them can be diminished.

Similar methods are being applied to the study of the problem of assessing the spreadability of butter.

In designing instruments to measure the body of cheese and butter, it is naturally most important that the properties actually measured should bear a close relation to what the practical man needs to know about his materials. The skilled cheese-maker judges the body of his cheese partly by prodding with his fingers and thumb, through the rind, and partly by examining the plug removed with an iron. Often he is aware that this cheese has better body than that, while finding it very difficult to express in words the precise reasons for his opinions. Certainly he does not judge by the physicist's concepts of viscosities and elastic moduli and the scientist must therefore attempt to find out how the craftsman's judgments are related to the results of the tests which have been invented. In other industries too many attempts have been made to control production quality in terms of simple physical properties of materials, resulting in a divorce between the control imposed by the instruments and the real requirements of the industry. There is yet time for the dairy industry to learn from these mistakes.

Meanwhile, the reliability of the cheese-maker, judge or grader can also be put to the test. All too little information is available as to the reproducibility of judgment of individual experts or the measure of agreement between experts. The smallest difference which can be detected by handling, in the viscosity of highly viscous liquids and in the elastic modulus of rubber (which is approximately elastic) has been measured for cheese-makers and others, but it is known that in matters of this kind there is very little " carry-over " of skill. Unfamiliar materials and conditions of testing, and lack of interest in or understanding of the purpose of such experiments may easily account for the fact that the experts do not as a rule show their superiority in such tests, especially if the experiments have to be at all prolonged. Just how " organised masses of experience " (" schemata ") are developed and used by the craftsman is a very complex problem which much interests the research worker.

More knowledge on such matters might help the craftsman to make the best use of his skill, and would certainly facilitate the training of apprentices and help those concerned with vocational guidance for young people considering careers in the dairy industry.

Rheological Measurements and Dimensions. There are many ways of measuring the viscosity of liquids. Their relative advantages depend on the nature of the materials, size of sample available, accuracy required, etc.

Viscosity (*q.v.*) is defined as a pressure ($ML^{-1}T^{-2}$) divided by a rate of shear (T^{-1}), and the unit is the Poise ($ML^{-1}T^{-1}$). The reciprocal is sometimes called Fluidity (*q.v.*) and the unit is the Rhe ($M^{-1}LT$).

When viscosity is measured by the rate of flow under known pressures, through capillary tubes, Poiseuille's Law (*q.v.*) is used. When the fall of a metal sphere through the liquid is timed, viscosity is calculated from Stokes' Law (*q.v.*).

Another popular method is to shear the liquid under test between concentric cylinders. As a rule, either a cylindrical vessel containing the liquid is rotated at constant speed, the twist on a wire from which a solid cylinder is suspended into the body of the liquid being measured, or the centrally-hung cylinder is rotated and the torque on the containing vessel is measured. (For the equations for calculating viscosity by these and other methods, the reader is referred to text-books on rheology.)

The elastic and plastic properties of cheese and butter are usually measured by compressing small cylinders of the materials under constant loads, or better, under loads so progressively increased as to ensure a constant force per unit area of the sample, even though the test-piece is increasing its area as its height is diminished.

The compression modulus is given by this force per unit area ($ML^{-1}T^{-2}$) divided by the relative change in height of the sample (dimensionless) and has therefore the dimensions $ML^{-1}T^{-2}$. If the material does not change its volume appreciably (as is the case with butter and most cheese), the rigidity or shear modulus is equal to 1/3 of the value of the compression modulus. These moduli have the same dimensions. (*See* standard text-books on Theory of Elasticity.) The treatment of plastic (non-recovered) deformations is too complex to be given in an article of this kind. Resilience has the dimensions of an energy ($ML^{-2}T^{-2}$) and Poisson's ratio is, of course, dimensionless. Bulk modulus has the dimensions of a pressure, ($ML^{-1}T^{-2}$).

Empirical tests for measuring the body of cheese and butter are too numerous to list in detail here. For practical purposes, the ball hardness tester, in which the depth of the indentation produced by a sphere of standard size pressed into the cheese under a fixed load, and the proportion of the indentation recovered elastically when the load is removed, is perhaps the most useful all-round instrument for the former material. Dutch rheologists have devised a useful penetrometer for measuring butter hardness: a rod attached to a spring is pressed into the butter and the compression of the spring when the rod penetrates the butter, under standard conditions, is recorded. The consistency of curd of hard-pressed types of cheese at the moment of settling (pitching) is best measured indirectly by superficial density, which indicates the extent to which the whey has been able to run out of the curd, being replaced by the much lighter air. This is not strictly a rheological measurement, but it reflects well the consistency of the curd as judged by the skilled cheesemaker.

Refs.: General Rheology: Scott Blair, (1938), *An Introduction to Industrial Rheology*, London; Scott Blair (1949), *A Survey of General and Applied Rheology*, London; Reiner (1949), *Deformation and Flow*, London; (1949), Reiner, *Twelve Lectures on Theoretical Rheology*, Amsterdam (more advanced); *Elasticity* (elementary): (1933), Searle, *Experimental Elasticity*, Cambridge; *Viscometry:* (1949), Merrington, *Viscometry*, London; *Applications to Dairying*: Baron, *The Mechanical Properties of Cheese and Butter*, London; *Rheology of Foodstuffs*, ed. G. W. Scott Blair, International Rheol. Monographs, Amsterdam.

RICHMOND'S FORMULA. *See* Solids-not-fat; Total solids.

RICKETS. A malformation of bones due to deficiency of vitamin D and calcium. *See* Nutritive values; Vitamins.

RIDEAL-WALKER. *See* Disinfectants.

RINGER SOLUTION. *See* Diluent.

RIPENING. *See* Butter; Cheese, p. 168; Cream.

RISING OF CREAM. *See* Cream layer; Fat globules; Stoke's law.

" ROGUES ". *See* Strays.

ROLL TUBE. A method for making colony counts in which a test-tube or special bottle is used instead of a Petri dish. *See* Plate count.

Refs.: Milk Testing; Thomas, B. F. *et al.* (1952), *LP*, **1**, 111; Clegg *et al.* (1951), *SAB*, **14**, 171; Higginbottom (1953), *SAB*, **16**, 16; Moir and Thomson (1950), *JDR*, **17**, 192; Hirsch (1948), *JGM*, **2**, 123; Howard and Fischer (1950), *DI*, **15**, 918; Thomas *et al.* (1940), *SAB*, p. 41; Wilson *et al.*, p. 151.

ROLLER DRIER. *See* Milk powder.

ROOTS. *See* Feeding of dairy cows.

ROPY MILK. Of the abnormal changes which sometimes take place in milk, one of the most common and persistent is that which gives rise to what is called " ropy " or " slimy " milk. Such milk, when poured from a jug, has a rope-like form. A spoon or wire dipped into the milk and then taken out draws after it thread-like strands sometimes more than a yard in length. Such an abnormal appearance naturally alarms the consumer, while the persistence of the trouble frequently causes great loss to the producer or retail seller.

Bacterial Ropiness. The ropiness which appears in the mixed milk of a herd several hours after milking, and which increases on allowing the milk to stand, is due to the growth of bacteria, which, as a general rule, gain access to the milk after it has left the udder of the cow, though in a few instances they may exist in the udder before milking. This kind of ropy milk, though abnormal and prejudicial from the seller's point of view, is quite wholesome and does not endanger public health.

" Garget " Milk. Ropiness, however, is sometimes observed in milk from individual cows, notably in cases of inflammation of the udder. In such instances, the cause may be either bacterial or non-bacterial. If the ropiness does not increase when the milk is kept and cannot be propagated by transference into another sample of fresh milk, it is probably due to the presence of fibrin and white corpuscles from the blood, which form masses of slimy material in the milk. Such milk (" garget " milk) may not cause other milk to become ropy, but organisms are present in the milk which may lead to infection being spread from one cow to another by the hands of the milker. For this reason, prompt attention should be given to all cows suffering from this disease, and all sources of infection avoided. Milk of this nature should not be used for food, and may be described as " stringy " milk to distinguish it from ropiness of bacterial origin.

Physical Ropiness. Ropiness which is only apparent when the milk is passing over the cooler is known as " physical ropiness ", and is due to films of proteins on the surface of the milk. This ropiness, however, is temporary and has no economic significance.

In this article the description " ropy milk " is confined to the first type of milk only. For " garget " or " stringy " milk *see* Abnormal milk and Mastitis.

Organisms Producing Ropiness in Milk. Ropiness may be produced by (1) micrococci ; (2) Gram-negative bacteria, including *B. lactis viscosus* and *Pseudomonas* ; (3) *B. aerogenes* and other coliform organisms ; (4) *Str. lactis* and other lactic acid streptococci ; (5) aerobic spore-formers ; (6) diphtheroids (*Corynebacterium*) ; and (7) *Lactobacillus.*

The ability to produce ropiness, however, is only a temporary character of most of these bacteria. The most important of the types mentioned are the micrococci and the Gram-negative bacteria (the so-called *Bacillus lactis viscosus* and *B. aerogenes*). These are commonly found in water.

Sources of Infection. The bacteria causing ropiness gain access to the milk after it leaves the udder. Unless properly sterilised, everything which comes in contact with the milk will increase the number of micro-organisms in the milk. It has been found that common sources of infection of " ropy milk " organisms are :

(1) Dirt from the cow or the worker.

(2) Contamination from milk utensils, cloths, strainers, coolers, churns, or any other material with which the milk comes in contact.

(3) Contaminated drinking water or marshy land which may infect the udders or flanks of the cows.

(4) The water used for washing up the utensils, etc. Such water may also infect milk passing over a leaky cooler.

(5) Straw, mouldy hay, bedding, manure, etc., which may show the presence of organisms producing ropiness in milk.

(6) Dust-laden air.

(7) Certain plants, *e.g.* butterwort.

(8) Feeding stuffs.

Of these, infected water, in which churns are placed to cool or utensils washed, is the most important. Feeding stuffs, bedding, and inefficiently sterilised utensils are the next most common sources of infection.

Tests Used for Ropiness in Milk. On the appearance of ropiness, it should first be ascertained whether the outbreak is due to bacteria by adding a few drops of the affected milk to some new milk in a clean glass. This glass should then be placed in a warm room and kept loosely covered to prevent dust from getting into it. The time taken for ropiness to appear should be noted, and is of the greatest importance from a practical point of view, as it can be assumed that ropiness which does not appear until after 3 days would not affect the sale of the milk. As contamination of milk utensils, etc., is a very common source of infection, immediate steps should be taken to investigate the possible sources of infection by washing and drying the udder and teats of a cow, then milking the cow, and allowing the milk to pass through all the usual stages on the farm. Samples from the milk should be taken at each stage, *e.g.* from each teat, from the milking pail, the cooler, the churn or other receptacle in which it may be placed, and put into clean glasses and the development of ropiness (if any) observed. In this way, infection from the cow or from the utensils may be discovered. Contamination of the cow's udder or flanks may be due to standing in marshy land or in a contaminated water supply. Such sources of infection may be investigated by putting the milk from unwashed cows into clean glass vessels and keeping the sample. The incidence of ropiness in it may then be studied. The possibility of infection by water used for washing the churns, etc., may be tested by adding some of the suspected water to a glass of fresh clean milk. Contamination by air may be discovered by leaving a glass of clean milk exposed in the dairy and in the cowshed. The possibility of infection from plants may be tested by addition of grass, etc., to the milk.

The results of these experiments will probably indicate the source of the trouble, and the measures described below for dealing with the discovered source of infection should be carried out. On an outbreak of ropiness, however, it would be as well to adopt the whole of the following precautions.

Preventive Remedial Measures. All too frequently when an outbreak of ropiness occurs, the whole of the utensils, dairy, etc., becomes infected with the bacteria causing the fault. Thus, even if the main source of infection be discovered by the tests indicated above, its removal will not necessarily result in the disappearance of the trouble unless the measures described below are followed :

(1) Dirt from a cow or worker may be avoided by attention to the cleanliness of the cow, of the worker, and of his clothes.

(2) Contamination by milk utensils, cloths, churns, etc. *All these must be thoroughly washed, then completely immersed in actively boiling water for a period of not less than* 10 *min., or sterilised by steam or, where suitable, by chlorine.* Scalding does not ensure the production of the state of cleanliness which is necessary. After the utensils, etc., have been boiled or steamed they *must not be rinsed with water before use*, but must be kept in a clean place and protected from dust. This may be accomplished by turning the milk pails upside-down and covering the utensils, etc., with a cloth which has been washed and either boiled or steamed. *Wooden vessels should not be used for milk as they may persistently retain ropy organisms.* It is not advisable to use wooden troughs even for washing milk vessels.

(3) Contaminated water supply or marshy land which may act by infecting the surface of the cow's udder or flanks. The cows must not be allowed to stand in the contaminated supply or to wander on to marshy land in which they may infect their udders. In some cases it has been found necessary to fence off such land.

(4) Contaminated water supply which may be used for washing utensils. If this is found to be the source of infection, consideration must be given to the possibility of procuring a cleaner supply of water, a task which may not be easy of accomplishment. Very considerable protection against the danger of this evil may be attained by efficient washing and sterilisation of all utensils as described under (2). The possibility of a leaky cooler must not be forgotten.

(5) Straw, mouldy hay, etc., may show the presence of the organisms which produce ropiness in milk. The custom of wiping the udder of the cow with an ordinary cloth before milking is a bad one. After washing their hands for milking, workers should not handle straw or fodder, nor should any such material be brought into the cow byre just before or during milking. The milking stool must be scupulously clean or it may infect the hands of the milker.

(6) Infection by air. Air infection may occur either in the cowshed or in the dairy, especially in hot, dry weather. It is best avoided by keeping these free from dust. The rooms where the milk is kept should be well cleaned. Wooden, cement or stone floors, walls or racks, etc., may first be washed down and then either disinfected by a solution of bleaching powder or, where possible, limewashed.

(7) Certain plants, *e.g.* butterwort, may be a source of infection. An investigation of the pasture land will demonstrate the presence or otherwise of plants which may be a source of infection. If there be any reason to suspect their presence, then the cows must be removed to another pasture.

(8) If feeding stuffs have been shown to be a source of infection, these should not be introduced into the byre until after milking.

Conditions Controlling Ropiness. In all infections, such as ropiness, two factors are necessary : (1) a continuous and heavy seeding of the milk with the causative organism, (2) conditions in the milk suitable for the growth of the bacteria and production of the slimy substances actually responsible for ropiness.

The common ropy milk organisms grow best in the presence of oxygen. It is found sometimes that ropiness is confined to the top layer, but usually the entire bulk is affected. Low temperatures favour the development of ropiness, because not only do the bacteria concerned grow best at rather low temperatures (their optimum is 20° to 25° C. as against 37° to 42° for *B. coli*), but low temperatures favour the production of the slimy substances by the bacteria.

Effect of Pasteurisation. Efficient pasteurisation (*e.g.* 145° F. for 30 min.) will, in all but exceptional cases, kill ropy milk organisms. *B. lactis viscosus* is readily destroyed, but *B. aerogenes* may withstand 63° C. (145° F.) for 20 min., especially if mature cells (as opposed to young growing cells) are present. For this reason, holding at 22° C. (70° F.) for 45 min. before pasteurisation has been recommended. This treatment allows the bacteria to grow, with the result that the ensuing population of young cells is more readily destroyed by heat treatment. It is essential, of course, to avoid post-pasteurisation contamination.

Mechanism of Slime Formation. Ropiness is caused by the formation of gums and mucins. The former are more common and are derived from lactose, which is fermented by *B. aerogenes* and other coliform bacteria, *Str. lactis* and similar streptococci, and the lactobacilli. Mucins are combinations of proteins with a carbohydrate radical, and may be produced by the peptonising bacteria (the micrococci, *B. lactis viscosus* and other Gram-negative bacteria, aerobic spore-formers, and diphtheroids). Sliminess, or ropiness, is intimately related to capsule formation. Thus, the " ropes " consist of long chains of bacteria held together by their capsules. In some cases the capsulation is a temporary accompaniment of cell proliferation, and the gummy substance is then dissolved in the milk. Such ropiness is destroyed by thorough agitation.

It has recently been noted that a bacteriophage found on vegetables readily induces strains of *B. aerogenes* to form slime. This may be an important factor in the prevalence of ropy types in feeding stuffs and on plants such as butterwort.

Refs.: Hammer; Rogers; Sundman (1953), *IDC*, **3**, 1420 (ropy sour milk); Thomas (1953), *DI*, **18**, 398, 493 (good bibliography); Thomas and McQuillan (1953), *DI*, **18**, 40; Thomas *et al.* (1950), *DI*, **15**, 715; Druce and Aynsley (1949), *SAB*, No. 1, 14; Murray (1949), *JAB*, No. 1, 17 (pasteurised milk); Thomas *et al.* (1948), *DI*, **13**, 854 (pasteurised milk); Murray (1946), *SAB*, p. 91.

ROQUEFORT. *See* Cheese, p. 199.

ROSE-GOTTLIEB METHOD. *See* Fat, determination of.

ROTATION OF CROPS. A system of successive crops calculated to keep the land in good condition. *See* Agriculture.

ROTATION, OPTICAL. *See* Optical rotation.

ROTHENFUSSER TEST. A test for heat-treatment based on the fact that amylase, the starch-splitting enzyme of milk, is destroyed at temperatures above 60° C. Residual starch is detected by the iodine test (blue colour).

Ref. : Gould (1932), *JDS*, **15**, 230.

ROUGHAGE. Fibrous, non-digestible matter in animal feeding stuffs. *See* Feeding.

ROUTINE LABORATORY TESTS IN THE DAIRY INDUSTRY. Routine tests are of the first importance in the dairy industry in which the milk of some 157,000 farmers has to be checked for chemical and bacteriological quality at regular intervals, usually every month. In addition, bulk milks and the pasteurised product have to be controlled at bottling and pasteurising depots, and at manufacturing creameries milk products such as butter, cheese, powder, condensed and evaporated milk have to comply with certain government standards. Elaborate analytical tests occupy a position of quite minor importance in the industry.

The following is a survey of the present position :

Sampling. The British Standards Institution has published a specification describing methods for sampling dairy products,[1] but sampling is still often unsatisfactory, especially for raw tanker milk, pasteurised milk [2] and certain manufactured products such as condensed milk. The tendency for fat to rise is the cause of errors in sampling for chemical analysis. A stainless steel plunger-dipper is probably the best solution for churn sampling, and a long-shafted propeller will probably prove to be the best ultimate solution for tanker sampling, since vigorous air bubbling methods may cause frothing and affect dye-reduction tests. In sampling for bacteriological analysis it is more important that samples should be taken aseptically than that the sample should be an accurate one in the chemical sense, especially if the sample has to be aged before testing as in the case of practically all tests for liquid milk.

Chemical Tests. (i) ***Fat.*** The Gerber test is the standard test for fat in milk for routine purposes in this country. Golding [3] has described a simple gravimetric method which, however, has not yet attracted general attention. Although the Gerber test is fairly simple and rapid, a method which avoided the use of strong acid would be desirable.

(ii) ***Solids-not-fat.*** This value is estimated from the specific gravity by the Richmond formula:

$$\text{S.N.F.} = \frac{F}{5} + \frac{G}{4} + 0{\cdot}14$$

(F = fat per cent., G = (sp. gr. — 1) × 1000). With care this method will give results usually within 0·1 per cent. of the true value, although some abnormal milks and carelessness in use of the hydrometer may give errors as high as 0·2 per cent., occasionally even higher. The B.S.I. method published in 1937 [4] involves warming of the milk samples to 40° and cooling to 20°. Although involving extra work this procedure, which can be used for any specific gravity method, gives greater accuracy. The most important source of error in this test is due to the Recknagel effect, *i.e.* the slow solidifying of the liquid fat globules. (*See* Milk testing; Richmond.)

(iii) ***Abnormal milk.*** The commonest cause of low solids-not-fat (as distinct from effects of breed, season, addition of water, etc.) is mastitis, and about one-sixth of our dairy cattle are affected to various extents with sub-clinical mastitis. Broadly speaking, bacteriological infection and chemical abnormality go together, and various quick spot tests have been suggested from time to time for the detection of diseased quarters in milking cows. An instrument, the Rapid Abnormality Indicator (R.A.I.), has now been devised for this purpose and depends upon the fact that whereas all four quarters of a healthy cow give milk of approximately the same sodium chloride content and therefore conductivity, infection in any one quarter almost invariably leads to a decrease in the lactose and an increase in the salt content. Any quarter, therefore, which gives a higher conductivity reading than the remainder may be considered as abnormal, and it has been suggested that a difference of 5×10^{-4} mhos, or greater, may be regarded as definitely significant; a difference of 15 or more indicates gross abnormality.[5] The R.A.I. is designed for use in the cowshed and will assess cows at a rate of 1 per min. An interesting side-line in the use of this instrument is that it may be used as a rough sorting-out test for watered milks in farmers' supplies. There is an inverse correlation between the solids-not-fat content and the conductivity of genuine herd bulks. If values are plotted on a scatter diagram the points of watered milks fall well outside the general cluster, and we have been able, using this instrument, to pick out known watered milks. For example, if a normal milk of 8·8 per cent. solids-not-fat had a conductivity of 40×10^{-4} mhos, and due to an outbreak of mastitis the solids-not-fat fell to 8 per cent., the conductivity would rise to, say 46. If, however, the low solids-not-fat were due to an addition of 10 per cent. water, the conductivity would fall to 36.[6] Naturally the test cannot compare in accuracy with the freezing-point test and must only be regarded as a rough " sorting-out " test, bearing the same relation to the freezing-point test as the platform rejection test has to the more accurate tests for the bacteriological quality of milk.

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[1] British Standards Institution (1949), B.S. No. 809.

[2] Watson *et al.* (1946), *SAB*, p. 56.

[3] Golding (1937), *JDR*, **8**, 275.

[4] British Standards Institution (1937), B.S. No. 734.

[5] Davis, Jones and Ward (1943), *SAB*, p. 43.

(v) ***Phosphatase test.*** Although this test is one for efficiency of pasteurisation it is really a biochemical test and is the most delicate of all the routine tests in common use. As from 1 March, 1946, this test and a special modification of the methylene blue test, became the statutory tests for pasteurised and heat-treated milks, the old plate count standard for pasteurised milk being dropped.[7] The phosphatase test is undoubtedly the most accurate of all the tests which have been proposed for controlling the efficiency of pasteurisation, but unfortunately one can easily obtain high results unless the necessary precautions are strictly observed. The most careful training of workers and constant supervision are essential for this test. The Aschaffenburg and Mullen form of the test may be recommended for routine control purposes. *See* Milk testing.

(vi) ***Freezing-point test.*** After a prolonged fight with legislative authorities the freezing-point test has been accepted as a reliable measure of the extent of watering of milk. Properly carried out it may be regarded as fool-proof, and it has been shown that factors which affect composition have only negligible effects on the freezing-point of genuine milk.[8] On the basis that the freezing-point of milk from single cows may range from − 0·530° to about − 0·560°, the former value has been accepted as a threshold line, so that a milk is not held to be watered unless the depression is less than 0·53° C. However, the mean depression is about 0·544°, so that officially watering up to about 3 per cent. is not detected. Calculation of the amount of water added on this basis is therefore always described as the minimum amount and it is probably about 3 per cent. more than that claimed from the result of the test. As with all other chemical and bacteriological tests, the accuracy of the test is increased the greater the bulking of the milk. Macdonald [9] has found that the freezing-point of bulk milk ranges from − 0·542° to − 0·548°, with a mean value of − 0·544°. By using this last figure as a basis for calculation, the proportion of any added water may be calculated with some degree of accuracy. It is often necessary to preserve milk samples destined for freezing-point tests when they have to be sent up from the country. Macdonald [10] has devised a method of estimating formaldehyde in such samples and of applying a suitable correction to the observed freezing-point. Evening samples may on rare occasions give abnormal results. *See* Freezing point test.

(vii) ***Treatment of soured samples.*** When analyses are made for legal purposes the sample has often become sour by the time it has reached the laboratory. Macdonald [11] has devised two methods for estimating the original fat and S.N.F. of decomposed milk, and a method for estimating the original freezing-point of decomposed milk.[12]

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[6] Davis and Loveys (1945), unpublished data.

[7] Ministry of Health, Milk (Special Designations) Regulations, S.R. and O. No. 10, 1946; S.I., No. 1589 (1949).

[8] Aschaffenburg and Veinoglou (1944), *JDR*, **13,** 267.

[9] Macdonald (1948), *A*, **73,** 423.

[10] Macdonald (1943), *A*, **68,** 171.

[11] Macdonald (1944), *ibid.*, **69,** 173.

[12] Macdonald (1945), *ibid.*, **70,** 323.

(viii) ***Temperature.*** The time-temperature conditions in the pasteurising of milk have to be controlled to within very fine limits, especially in the high temperature-short time process. One of the criticisms that have been levelled against the " in-bottle " method is that we do not know exactly what is the temperature of the milk in the different parts of the bottle during the process. A midget temperature-recording apparatus that can " follow-through " the bottle during " in-bottle " pasteurisation or sterilisation for sterilised milk has recently been devised. *See* Pasteurisation ; *LCDP.*

(ix) ***Time of flow.*** The new high temperature-short time process requires milk to be held at a temperature of at least 161° F. for not less than 15 sec. The ordinary methods available for timing the flow depend upon the addition of brine (conductivity method) or of certain chemical reagents (colorimetric method) [13] and so cannot be used during the actual processing of the milk. Any apparatus which permitted the timing of the flow during commercial pasteurisation would be a valuable addition to the temperature recorder which is now an essential part of all pasteurising equipment.

This problem has been discussed by Davis[13a] ; a method for measuring holding times during pasteurisation by the H.T.-S.T. process is described in this paper.

Bacteriological Tests. Routine chemical tests can easily be assessed in terms of well-tried gravimetric methods, but with bacteriological tests there is no one yard-stick which is generally accepted and embraces all the information which we require about the milk.[14] Before we can assess the value of any routine bacteriological test we have to take into consideration (1) the quality used as a criterion or yard-stick (*e.g.* bacteriological numbers, keeping quality, etc.) ; (2) correlation of the proposed tests with this quality ; (3) practical aspects (*e.g.* time, skill required, apparatus, etc.). It may be noted that of these three only (2) can be assessed objectively and (1) and (3) must inevitably remain to a large extent a matter of opinion. Routine bacteriological tests for milk fall into two sharply defined categories : (*a*) rapid tests for detecting dirty milk (platform tests), and (*b*) longer laboratory tests for grading the producers' milks.

(i) ***Platform tests.*** Under the National Milk Testing and Advisory Scheme, a special modification of the resazurin test [15, 16, 17] was adopted for platform testing. This test is considered to be more accurate than the tests formerly in use (smell, taste, sediment, and titrable acidity), but it is appreciably longer than these. Unfortunately, there is no test which can take the place of smell. Many factors control the smell of any given churn of milk, and there are many types of smell; not all of which are due to bacteria in the milk. The rapid resazurin test takes 10 min., and a 10 sec. test is urgently required. For some years we have been working on this problem and have made some technical progress on devising a " sour milk tester " which will register the pH of a milk on a meter on the wall of the dairy platform, but we have not yet devised an apparatus which we could with confidence put in the hands of the ordinary dairy operative.[18]

(ii) ***Routine grading tests.*** The N.M.T.A.S. adopted a temperature-compensated resazurin test for the routine grading of producers' milks. This test has been the subject of much controversy, but many of the critics are not aware of the difficulties which confronted the committee which decided to use this test. All the recognised tests for the bacteriological quality of milk have their advantages and disadvantages, and no single test gives us all the information we want. The 1 hr. resazurin test[19, 20, 21, 22] which is the basis of the temperature-compensated modification, is not quite as accurate as the methylene blue test which takes some 4 or 5 hr. It is, however, considerably quicker, and quite adequate for the routine grading of producers' milks into three categories: good, doubtful, and bad. The resazurin test, unlike the methylene blue test, is appreciably sensitive to mastitis on account of the fact that a high cell content will play its part in the reduction of resazurin to resorufin.[19, 21] Whether this is desirable or not is again a matter of opinion. The resazurin test involves a matching of colours in a comparator,[23] and to permit the test to be used when good daylight is not available, a fluorescent lamp may be used to give results which agree extremely closely with those obtained in daylight.[24] Apart from pathogenic organisms, the two most important components of the " hygienic quality "[14] of raw milk are (1) bacteriological numbers, and (2) keeping quality.

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[13] Dummett and Mongar (1944), *DI*, **9**, 264.

[13a] Davis (1953), *DI*, **18**, 682.

[14] Davis (1945), *SAB*, p. 74; *FM* (1946), **21**, 5; *JRSI* (1950), **70**, 227.

[15] Davis (1939), *DI.*, **4**, 221.

[16] Ministry of Agriculture (1942), C.150 T.P.Y.

[17] Barkworth, Davis, Egdell, Rowlands and Watson (1943), *DI*, **8**, 215.

[18] Davis and Ward (1944), *BJ*, **38** (1), ix.

To obtain any reliable and accurate measure of these two qualities requires the use of two tests, but it is doubtful whether the industry would be prepared to carry out two tests such as the plate count or direct microscopic count for bacterial numbers *and* a dye-reduction test for keeping quality.

When milk is pasteurised an entirely new problem is raised as there is no certain relation between the bacterial counts and keeping qualities before and after pasteurisation. The plate count standard of 100,000 per ml. for pasteurised milk has now been dropped—partly because of this lack of relationship, but also because raw milk supplies frequently contain counts of thermoduric organisms in excess of 100,000 so that the most efficient pasteurisation will not give a product having a plate count of less than 100,000. For this reason, it is likely that special attention will be paid in the near future to the numbers of thermoduric organisms in farmers' supplies. Unfortunately, there is no well-established simple method for testing farmers' supplies in this respect—the laboratory pasteurisation test is, of course, too laborious and expensive for routine purposes. Three new methods have been described—the autoclaved slide, incubation of the sample for 2 hr. at 58° to 60° C.[25] and a loop cultivation method.[26] The modern outlook on clean milk production lays stress on cooling without contamination, and cleaning and sterilisation of utensils as the outstanding factors in production.[27] In other words, it is more important that milk should be taken and handled in clean sterile utensils and well cooled than that any other precaution should be taken. A high count of thermoduric organisms may always be traced to unclean utensils, and milking machines are frequently the cause. A simple test for thermoduric organisms would thus form a useful routine test for the sterility of utensils, although it would be of limited use as a low thermoduric count (*e.g.* < 10,000) would not prove that sterile utensils had been used. However, it would be reasonable to expect that a farmer's supply should give a thermoduric count not exceeding 1000. *See* Bacteriological grading; Clean milk production; Thermoduric bacteria.

(iii) ***Bulk milk.*** The bacteriological grading of bulk milk was standardised[28] and the resazurin and titratable acidity tests adopted under the N.M.T.A.S. for this purpose. It may be emphasised that although titratable acidity

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[19] Ramsdell *et al.* (1935), *JDS*, **18**, 705.

[20] Thomas and Davies (1940), *Welsh J. Agric.*, **16**, 231.

[21] Davis, Newland and Knuckey (1943), *DI*, **8**, 23, 71 and 115.

[22] Anderson and Wilson (1945), *JDR*, **14**, 21.

[23] Davis and Thomas (1940), *DI*, **5**, 244.

[24] Davis and Newland (1943), *ibid.*, **8**, 555.

[25] Mallmann and Bryan (1943), *Bull. Int. Assoc. Milk Dlrs.*, **35** (13), 175-88.

[26] Myers and Pence (1941), *J. Milk Tech.*, **4** (1), 18-25.

[27] Davis, Newland, Wilby and Arthurs (1945), *SAB*, p. 69.

[28] Ministry of Agriculture (1944), Form No. B.564/T.P.B.

as applied to producers' milk is unreliable on account of the fact that mastitis may lower the acidity,[29] it is a very satisfactory test for bulk milk. It is, however, essential that the titratable acidity be measured by a standardised technique because many factors, of which the most important is the concentration of the phenolphthalein indicator, can affect the result appreciably. A standardised technique has been proposed and this has been generally adopted.[30] Temperature is so important a property of bulk milk supplies that it should be considered on the same basis as a bacterial test and the following standards have been adopted for bulk milk : (1) the 10 min. resazurin disc reading shall be not less than 3 ; (2) the titratable acidity shall not exceed 0·17 per cent. " lactic acid " ; (3) the temperature shall not exceed 43° F. *See* Milk testing.

There has been a tendency lately for some wholesalers to heat-treat their supplies in order to facilitate acceptance by the second buyer. Such a practice is undesirable because a second heat-treatment may lead to problems in keeping quality. There is no recognised test for the detection of mixtures of raw and pasteurised milk or of " shocked " milk, *i.e.* milk heated momentarily to 160° F. or for, say, 15 sec. to 150° F. It might be possible to devise such a test by a suitable modification of the phosphatase test or by comparing the ratio of viable to non-viable organisms in the milk.

(iv) ***Pasteurised and heat treated milks.*** The new statutory methylene blue test [7] which replaces the plate count involves holding the sample at atmospheric temperature (but not exceeding 65° F.) from the time of sampling on the day of delivery to the consumer until 9 to 10 a.m. the next morning, and then subjecting the milk to a methylene blue test at 37°. If the dye is reduced in ½ hr. the sample fails the test. This standard is easy to attain in winter and is reasonable at moderate temperatures. Aschaffenburg has proposed a turbidity test for sterilised milk [31] and this was adopted in the 1949 Regulations.[7] *See* Legal aspects.

(v) ***Pathogenic bacteria.*** No simple quick test is available or is ever likely to be available for tuberculosis and other pathogenic bacteria in milk in spite of the popular conception of the function of a dairy bacteriologist. Indeed such a test is unnecessary because efficient pasteurisation and avoidance of post-pasteurisation contamination will make it impossible for milk to contain these disease-producing bacteria. *See* Diseases, human.

(vi) ***Physical tests.*** These have the advantage that they are much quicker than chemical tests and speed is a great factor in routine control of quality and manufacture. The most important property in dairy products generally is moisture, as this must either be kept below certain limits (*e.g.* as in butter) or in other cases has to be maintained below a certain point in order to maintain keeping quality of the product (*e.g.* as in milk powder). Methods that have been tried for this purpose include specific gravity, dielectric constant, and conductivity. Where the composition of the materials or final product is practically constant or known, as in bulk milk, it is sometimes possible to follow the moisture content during the manufacturing process by changes in a physical property such as the refractive index. *See* Butter; Milk powder.

(vii) ***Condensed milk.*** Condensing involves the evaporation of water and the addition of sucrose to give a final concentration of about 26 per cent. milk solids and 45 per cent. sucrose. The " striking point " has to be determined very quickly and with some accuracy as too high a moisture may result in poor keeping quality and too low a moisture may result in thickening. Present practice tends to rely on specific gravity for this purpose as this is correlated linearly with the solids content and so inversely with the moisture content. The measurement

[29] Davis (1941), *FM*, **16**, 133.

[30] Davis and Sadek (1942), *MI*, **22** (10), 43.

[31] Bull. Min. Hlth. (1947), **6**, 159.

of the specific gravity of a hot viscous liquid is not an easy problem and improvements on the present hydrometer method would be welcome. The projection refractometer has been adopted with advantage in some condensing plants. Both these properties (specific gravity and refractive index) bear a linear relationship to the solids content, but viscosity, which was formerly used to a considerable extent, is not now relied upon for the control of the solids content, although the inflexion of the viscosity-total solids curve gives a greater sensitivity at the end point. Seasonal variations in the initial viscosity of the milk influence the test. However, viscosity may be useful for giving additional information in the control of the process. *See* Condensed milk.

(viii) ***Evaporated milk.*** The control of evaporated milk is simple in that there are no complications introduced by the addition of sucrose and a conductivity method has been suggested for controlling the process.

(ix) ***Cheese.*** Cheesemaking has always been, and still is, very largely a craft, and about the only scientific test which has been adopted by cheesemakers generally is the titratable acidity test. The determination of the timing of the various steps in cheesemaking (cutting the coagulum, pitching the curd, drawing the whey, and grinding the curd) are extremely important and considerable experience and intelligence are required of the cheesemaker in order that these operations are correctly carried out and a first-class cheese produced. Considerable work has been done by Scott Blair and his colleagues in an effort to provide simple objective tests to replace the highly subjective tests (feeling the coagulum and squeezing the curd) which are normally used. Special apparatus for measuring the elasticity of the coagulum, etc., and the superficial density of the curd near the pitching point[32, 33, 34] have been described and the latter apparatus promises to be of considerable use. It has not yet been taken up generally by cheesemakers and a considerable educational effort will be required in order to persuade the practitioners of a traditional craft to employ new scientific methods. *See* Cheese; Rheology.

(x) ***Plant sterility.*** The cleaning of dairy equipment involves two criteria: (1) the removal of organic matter which might serve as food for bacteria and (2) the removal or destruction of the bacteria themselves. The amount of organic matter remaining in a utensil such as a bottle or churn may be estimated by allowing a solution of chlorine of known strength to remain in it for 24 hr. at 18°, the fall in concentration of chlorine being a measure of the organic matter. A control solution must, of course, be held in a thoroughly clean utensil under the same conditions.[35] Two methods are available for testing sterility. Where the nature of the utensil permits, a known amount of sterile quarter-strength Ringer solution may be used to rinse out the utensil and an aliquot portion of the rinse plated in the ordinary way (bottles and churns).[36, 37] It is, of course, impossible to use this method for large surfaces and large vessels such as storage tanks and road and rail tankers. For these a swabbing method is used, a swab of sterile cotton wool being rubbed over a square foot of the surface and then squeezed out in a known amount of sterile Ringer solution. Standards for dairy utensils were adopted under the N.M.T.A.S. of one colony per ml. capacity or 5000 colonies per square foot (approx.).[38] *See LCDP.*

(xi) ***Detergents.*** The measurement of detergent strength in the dairy industry is one of considerable importance. It can, of course, be determined by

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[32] Scott Blair and Coppen (1941), *JDR*, **12,** 44.

[33] Scott Blair, Coppen and Dearden (1941), *ibid.*, 170.

[34] Scott Blair and Scott Blair (1941), *ibid.*, 322.

[35] Davis, J. G. (1943), unpublished observations.

[36] Mattick and Hoy (1937), *Bottle Washing and Bottle-washing Machines*, N.I.R.D.

[37] Ministry of Agriculture (1944), C.168/T.P.Y.

[38] Ministry of Agriculture (1944), C.195/T.P.Y.

titration with decinormal acid,[36] but this involves laboratory facilities and the withdrawal of the solution, and is rather cumbersome for measurement purposes. The use of a *p*H indicator has been investigated and quinizarin-6-sulphonic acid suggested.[39] A detergent strength meter has been described [39] and it is extremely probable that all washing machines in the dairy industry in which detergent is used will be equipped with such meters in the future.

Refs.: Milk Testing; LCDP; Davis and Ashton (1951), *JSDT*, **4**, 78 (laboratory control).

ROUTINE RESAZURIN TEST. *See* Resazurin; National Milk Testing and Advisory Scheme.

RUMEN. The paunch or first chamber of the stomach of a ruminant. *See* Digestion.

Ref.: Doetsch and Robinson (1953), *JDS*, **36**, 115 (bacteriology).

RUMINANTS. A group of even-toed, divided-hoofed animals. They lack front teeth in the upper jaw and chew the cud. They are usually horned.

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[39] Davis, Ward and Liddiard (1944), *SAB*, p. 53; Davis (1951), *FM*, **26**, 13, 53.

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SACCHAROMYCES. A genus of yeast (p. 1130).

SAFETY.

Refs.: Webster (1953), *LP*, **2**, 552, 601, 655 (laboratory).

SAFFRON. A yellow colouring matter possibly used at one time in milk.

SAGE. *See* Cheese, p. 200.

SAHARA MILK DRIER. A vacuum roller drier consisting of an inner evacuated drum which is heated by spray pipes from an outer drum. The dried film in the inner drum is scraped off and finely powdered by steel balls. *See* Milk powder.

SALE OF FOOD. Milk and other dairy products are controlled by a number of Acts and Orders. *See* Food and Drugs Act; Legal aspects.

Refs.: Bell; Swift; Ashford and Savage (1938), *The Food and Drugs Act*, London.

SALICYLIC ACID. Hydroxybenzoic acid, $C_6H_4(OH) . COOH$, formerly used for the preservation of milk samples. For detection *see* Revis (1912), *A*, **37**, 346 and Hinks (1913), *A*, **38**, 555.

SALMONELLA. A genus of Gram-negative, non-spore-forming, facultatively anaerobic, motile rods occurring in the intestinal canal of mammals and birds. Various species are the cause of food poisoning, enteritis, and infections of the paratyphoid type. *See* Classification; Diseases; Food poisoning.

Refs.: Bergey; Wilson and Miles.

SALOLASE. An enzyme decomposing salol (phenyl salicylate). Its presence has been reported in milk.

SALT. (i) The common name for sodium chloride (table salt) NaCl. (ii) Any combination of an acid with a base or metal

$$\mathrm{NaOH} + \mathrm{HCl} \rightarrow \underset{\text{sodium chloride}}{\mathrm{NaCl} + \mathrm{H_2O}}$$

$$\mathrm{2KOH} + \mathrm{H_2CO_3} \rightarrow \underset{\text{potassium carbonate}}{\mathrm{K_2CO_3} + \mathrm{2H_2O}}$$

$$\mathrm{3Ca(OH)_2} + \mathrm{2H_3PO_4} \rightarrow \underset{\text{calcium phosphate}}{\mathrm{2Ca_3(PO_4)_2} + \mathrm{3H_2O}}$$

The term " minerals " is sometimes used for the salts in milk. The *ash* consists of those salts not decomposed by dull red heat. *See* Chloride; Constituents.

Ref.: B.S. 998 (1941) (dairy salt).

SALTING. *See* Butter; Cheese, p. 175.

SALTY MILK. Mastitis can produce pathological changes in milk, and late lactation, etc., physiological changes resulting in a decrease in the lactose and an increase in the salt content. Such milk tastes salty and some farmers and cowmen will actually taste the milk as a test for mastitis. This procedure is not recommended as apart from the subjective error, on rare occasions mastitis may be due to an organism pathogenic for man. This rise in salt content is the basis of the Rapid Abnormality Indicator (p. 886). *See* Abnormal milk; Mastitis.

SAMNA. The Egyptian analogue of ghee (p. 489).

SAMPLING OF MILK AND MILK PRODUCTS. Samples are usually taken either for chemical analysis or for bacteriological examination, or for both. For the first the thorough mixing of the bulk is of the utmost importance as the error of analytical methods is usually of the order of 1 per cent.; for the second aseptic precautions and sterile containers are the prime consideration and the mixing is less important than for chemical tests as the error of bacteriological test is of the order of 20 per cent. or higher. For the third requirement, a truly representative sample must be taken aseptically into sterile containers. Contrary to popular belief correct sampling is a difficult matter and one that requires the most careful attention. No description of methods can take the place of proper training and adequate experience. It is impossible to lay down fixed rules to be followed in every case, and particular circumstances may render some modification of the recommended method desirable. Sampling should always result in a true average of the bulk being obtained.

Where the product will be examined for flavour it should be protected from light and stored in a cool place.

The following methods are reproduced from B.S. 809 (1949) by permission of the British Standards Institution:

Technique of sampling. Samples may be required for chemical or bacteriological examination, but the basic principles of sampling are the same in both cases. All precautions shall be taken to prevent contamination and adulteration.

For chemical purposes sterile equipment is desirable but where this is impracticable, all equipment shall be clean and as dry as possible.

For bacteriological purposes, all equipment, including plungers, sample bottles, rubber stoppers, etc., shall be sterile. Equipment shall be sterilised by one of the following methods:

(*a*) Hot air oven for 2 hr. at 160° to 170° C. (*b*) Autoclave for 15 min. at 120° C.

In some circumstances the following treatments are satisfactory:

(*c*) Steam for 1 hr. at 100° C. (Equipment treated by this method shall be used immediately.)

Rubber stoppers shall be sterilised in the autoclave as in (*b*), but treatment by immersion in boiling water for 30 min. may be satisfactory if they are used immediately.

Selection of samples. (*a*) *Bulk units.* If the product is supplied in bulk units (cans of milk, large cheese, casks or boxes of butter, barrels or cans of condensed or dried milk and containers of ice cream, etc.) the number of random units to be sampled shall be as follows:

Total number of units	*Number of units to be selected*
1	1
2 to 5	2
6 to 60	3
61 to 80	4
81 to 100	5
over 100 [1]	5 plus 1 for each additional 100 units or fraction thereof.

[1] The figure for units over 100 is for guidance only, and it is recommended that the testing laboratory be consulted regarding number of units to be selected.

The testing laboratory may, within its discretion, instruct the sampler to submit: (i) Samples from each unit selected, or (ii) one or more composite samples consisting of aliquot portions from each unit selected.

Method (ii) should be applied only where the product is likely to be of fairly uniform composition, *e.g.* where the consignment to be sampled is produced from a quantity of properly bulked milk, and where variations in composition from unit to unit are therefore small.

Where there is a possibility of wide variations between different units, *e.g.* with consignments of liquid milk from an individual producer, every unit should be sampled.

(*b*) *Retail units.* When sampling retail units (bottles of milk, small tins of condensed or dried milk. cream, ice cream, small packages of processed cheese, etc.) it is advisable to vary the incidence of samples according to circumstances.

For example, the determination of the quality of a consignment may require treatment differing from that designed to detect isolated failure to reach a known standard. Sampling will also vary according to knowledge, if any, of the division of the consignment into manufacturing "batches". The testing laboratory should be consulted regarding numbers and method of selection of samples.

For consignments expected to be of uniform quality, the following minimum numbers of units shall be selected at random from separate crates, cases or packages:

Total number of units	*Number of units to be selected*
1 to 100	1
101 to 1000	2
1001 to 10,000	4
over 10,000	4 plus 1 for each additional 2500 units or fraction thereof.

The samples shall consist of the unopened retail unit(s) selected.

Sample containers. (*a*) *Bottles* (*for liquids*). Sample bottles shall be made of good quality glass suitable for sterilisation. The following sizes of sample bottles shall be used:

Nominal capacity	*Internal diameter neck*	*Internal diameter bottle*	*Height of bottle*	*Height to shoulder (approx.)*	*Weight*	*Capacity (brimful)*
oz.	*in.*	*in.*	*in.*	*in.*	*oz.*	*oz.*
3	0·75 ± 0·02	(1·68 ± 0·03 at shoulder) (1·64 ± 0·03 at base)	4·88 ± 0·03	2⅜	4	3¼
4	0·75 ± 0·02	1·80 ± 0·03	5·38 ± 0·03	2¾	5	4¼
6	0·75 ± 0·02	2·09 ± 0·04	6·03 ± 0·04	2 9/16	7	6¼
8	0·75 ± 0·02	2·29 ± 0·05	6·70 ± 0·05	3⅛	8½	8¼

NOTE.—The nominal capacities are the actual capacities of the sample bottles if used with a cap, allowing approximately ¾ in. between the top of the milk and the cap for mixing by shaking.

The neck of the sample bottles shall be so made as to allow the bottle to be closed by means of either a screw cap with a liner of rubber protected with a grease-proof, non-absorbent, insoluble material which will not impart any deleterious odour or taste to any foodstuff, or by a rubber stopper.

If desired, the sample bottles may be sand-blasted over a suitable area for inscription.

(*b*) *Jars* (*for semi-liquids and solids*). The jars shall be made of glass, metal or other suitable material which can be sterilised easily. The following sizes of sample jars shall be used:

Nominal capacity	*Internal diameter*	*Height*
oz.	*in.*	*in.*
2	1·74 ± 0·03	2·54 ± 0·03
4	2·28 ± 0·04 (at shoulder) 2·21 ± 0·04 (at base)	2·83 ± 0·03
8	2·81 ± 0·03	3·34 ± 0·03

The jars shall be closed by means of a screw cap with a liner of rubber, protected with a grease-proof, non-absorbent, insoluble material, which will not impart any deleterious odour or taste to any foodstuff.

If desired, the sample jars may be sand-blasted over a suitable area for inscription.

Transport of samples. Any product which is to be examined for flavour, shall be protected from light and not be exposed to odours which may be absorbed by the product.

(*a*) *Samples for chemical examination.* It is advisable for samples for chemical examination to be delivered for testing on the day they are taken. Where this is impossible, adequate precautions shall be taken to prevent deterioration and exposure to high temperatures during transit. In some cases, a suitable preservative, *e.g.* mercuric chloride, potassium dichromate or formaldehyde may be added to liquids to prevent deterioration; if so, this shall be indicated on the label.

(*b*) *Samples for bacteriological examination.* If the tests are to determine the bacteriological condition at the time of sampling, the sample shall either be tested immediately or iced and maintained at a temperature not exceeding 5° C. until tested. If the sample is to be aged prior to testing, the method of transport shall be in accordance with the instructions of the bacteriologist concerned. Retail packages of ice cream shall be maintained in the solid state at a temperature not exceeding – 10° C.

B. Milk, Cream, Buttermilk and Whey. ***Apparatus.*** Plungers and dippers should preferably be of stainless steel, but adequately tinned iron or other suitable material may be used. If solder is employed, it shall be capable of withstanding a sterilising temperature of 180° C. All surfaces shall be smooth and free from crevices or projections.

(*a*) *Plungers or agitators for liquids.* In general, plungers or agitators should be of sufficient area to produce adequate disturbance of the product, and sufficiently light in weight for the operator to be able to move them rapidly through the liquid. In view of the differing shapes and sizes of containers, no specific design of plunger can be recommended for all purposes.

A form of plunger recommended as being suitable for the mixing of milk in buckets or in cans consists of a disk 6 in. in diameter, perforated with 6 holes each ½ in. in diameter on a pitch circle of 4 in. diameter, the disk being fixed centrally to a metal rod, the other end of which forms a loop handle. The length of the rod, including the handle, should be approximately 3 ft. 3 in.

A suitable plunger for use with road and rail tanks has a rod not less than 6 ft. in length and is fitted with a disk 12 in. in diameter perforated with twelve holes each 1¼ in. in diameter on a pitch circle of 9 in. diameter.

(*b*) *Dippers.* Dippers shall be fitted with a solid handle at least 6 in. in length, but where the dipper is to be used for mixing purposes, the handle shall be 15 in. in length. The capacity of the dipper shall be not less than 3 oz. It is an advantage for the handle to be bent over. The tapered form of the cup permits nesting of the dippers.

(*c*) *Plunger-dippers.* The plunger and dipper may be combined.

Definitions. For the purposes of this section the following definitions shall apply:

One transfer. Pouring from one vessel to another.

One plunge. Pushing the plunger quickly to the bottom of the vessel and back again.

Milk. (*a*) *Individual animals.* Normally the entire milking, including the strippings, shall be placed in one vessel and thoroughly mixed, either by a number of transfers or by plunging.

(i) *Hand milking.* If the sample is taken immediately on completion of milking, a single transfer or plunge will suffice.

(ii) *Machine milking.*

(A) *Bucket system.* The entire strippings from the cow shall be added to the rest of the milk and mixed either by four transfers or by six plunges. If the cow is not stripped, the sample may be taken as for hand milking.

(B) *Auto-recorders.* The whole of the milk may be transferred from the weighing-jar to a bucket, the strippings added and a sample taken as in the bucket system. Alternately, where the machine is provided with a sampling attachment, the milk and the strippings may be adequately mixed by bubbling air through the weighing-jar before drawing a sample.

(*b*) *Small vessels—Milk buckets and cans.* The milk shall be mixed either by 6 transfers or by 10 plunges. When these methods are not possible, the milk may be mixed by vigorous stirring and plunging with a long-handled dipper for not less than 30 sec.

(*c*) *Large vessels—storage, rail and road tanks.* The methods are dependent upon a number of factors, *e.g.* the length of time the milk has been standing in the tanks, and the conditions of storage. It is, therefore, impracticable to lay down any rigid procedure for sampling, but the following are recommended :

In all cases the milk shall be thoroughly mixed by a plunger, a mechanical agitator, or by compressed air.

(i) When samples are taken within 30 min. of filling the vessel the milk shall be vigorously plunged for 5 min. When the milk has been in the tank for a longer period, the milk shall be plunged for 15 min.

(ii) When using a mechanical agitator or compressed air, the mixing shall continue until such time as complete agreement is obtained between samples taken at the manhole and the outlet cock. The time required will be learned by experience.

Cream. The method used shall be as described for milk above, but the following precautions shall be observed :

The cream shall be plunged not less than 10 times, the position of the plunger being moved from place to place to ensure that the whole of the cream at the bottom of the vessel is thoroughly agitated and mixed with the upper layer. To avoid whipping and churning, the disk of the plunger shall not be brought above the surface of the cream.

Buttermilk. The method used shall be as described for milk above and a sample shall be taken immediately, before fat or other solid matter has time to separate.

Whey. The method used shall be as described for milk above.

Sweetened Condensed Milk. ***Barrels, drums and other bulk containers.*** The sampling of bulk containers of sweetened condensed milk may be a matter of extreme difficulty particularly when the product is not homogeneous and is highly viscous.

(*a*) *Recommended method.* One end of the container, previously thoroughly cleaned and dried to prevent foreign matter falling into the bulk during the opening process, shall be removed. The contents shall be mixed by using a suitable implement such as a broad-bladed metal stirrer which is long enough to reach the bottom of the container and preferably having one edge shaped to the contour of the container. The blade shall be scraped round the sides and bottom of the container to remove any adhering lactose crystals or separated butterfat. The contents shall be thoroughly mixed by a combination of rotary and vertical movements, with the stirrer inclined diagonally, taking care to avoid incorporation of air in the sample. The stirrer shall be withdrawn and the condensed milk adhering to it shall be transferred into a suitable receptacle by means of a spatula or spoon. The mixing and withdrawal shall be repeated until 8 to 9 lb. are obtained. This shall be mixed until homogeneous and a sample taken of not less than 4 oz.

(*b*) *Alternative method.* When removal of the end of a container is impracticable, sampling may be performed through the bung hole. This method is reliable only with condensed milk which flows readily and is of uniform texture. The contents shall be mixed by inserting a round hardwood stick (about 4 ft. long by 1¼ in. in diameter) through the bung hole, and after exploring and stirring as far as possible in all directions, the stick shall be withdrawn and a sample prepared as in (*a*).

Butter and Cheese. ***General.*** Samples shall be transferred immediately to air-tight sample jars and shall not come into contact with paper or absorbent surfaces.

Apparatus. Butter and cheese triers shall be made from good quality, hard steel which is free from metallic odour and easy to clean and sterilise.

Butter (bulk containers). From box butter, 3 cores shall be drawn by inserting a trier diagonally through the block from 3 corners of the opened end. From cask butter, 3 cores shall be drawn by inserting a trier at 3 points equidistant on the circumference of one end of the block and directed through the centre of the block.

The sample shall comprise 3 parts approximately equal in weight, taken as follows:

(*a*) The top third of the first core; (*b*) the middle third of the second core; (*c*) the bottom third of the third core.

When 3 or more boxes or casks are to be sampled 1 core only may be taken from each box or cask.

The sample shall consist of not less than 2 oz. when the bulk is less than 1 cwt. and not less than 4 oz. when the bulk is 1 cwt. or over.

Cheese. Any sample of cheese shall be not less than 2 oz.

For the examination of surface contamination the whole unopened package of cheese, either wrapped or in tins, shall be submitted.

(*a*) *Hard cheese over* 3 *lb. in weight.* The trier, which shall be not less than 5 in. in length, shall be inserted horizontally to its full length at any point on the side of the cheese not less than 3 in. from either crown except where the depth of the cheese is less than 6 in. This process may be repeated twice to give three plugs of cheese, the trier being inserted on each occasion at points approximately equidistant from each other. The plug(s) excluding the outer end(s) to a depth of ¾ in. (which shall immediately be replaced in the cheese) shall constitute the sample.

(*b*) *Hard cheese* 3 *lb. or less weight, and soft cheese.* Either (i) a complete cheese shall be submitted for analysis or (ii) a wedge shall be removed by two cuts radiating from the centre of the cheese. The rind or mould skin shall be removed and the remaining portion placed in a sample jar.

(*c*) *Processed cheese in blocks.* Either a slice consisting of a cross section of the block of cheese, or a plug taken by inserting a trier through the length of the block of cheese, shall be placed in a sample jar.

Dried Milk, Dried Buttermilk, Dried Whey, Dried Malted Milk, Milk Sugar, and other Dried Milk-Products. ***Sampling of bulk containers over 3 lb. in weight.*** Any dirt, dust, or foreign matter shall be removed from the exterior of the container prior to opening.

(*a*) *Recommended method.* The contents of the container shall be transferred to another container of larger size and mixed thoroughly. A sample of not less than 4 oz. shall be transferred to an air-tight jar.

(*b*) *Alternative methods.* (i) A suitable screw-type steel sampling tube may be used. The tube shall be held stationary and the centre rod rotated so that the tube is drawn steadily into the powder, using slight pressure when necessary, to ensure an even rate of penetration. When the tube reaches the bottom of the container the sampler shall be withdrawn and its contents delivered into a suitable receptacle by reversing the direction of rotation of the centre rod. Two samples shall be taken in this manner and mixed thoroughly. Not less than 4 oz. shall be transferred to a clean, dry receptacle of metal or glass, capable of air-tight closure and of sufficient size to allow mixing by shaking.

(ii) At least the top 6 in. of the contents of the container shall be thoroughly mixed by a suitable metal implement such as a flour scoop, and not less than 4 oz. transferred to a clean, dry receptacle of metal or glass, capable of air-tight closure, and of sufficient size to allow mixing by shaking. *See* Accuracy; Butter; Cheese; Condensed and evaporated milk; Laboratories, organisation of; Legal aspects; Milk powder; Statistical formulae.

Ref.: Hall (1951), *JDR*, **18**, 151 (individual quarters).

SANDINESS. The sensation experienced in the mouth when a food such as ice cream or condensed milk contains tiny crystals of sugar or ice. *See* Condensed milk; Ice cream.

SAPONIFICATION. The hydrolysis of fats, and, loosely in the detergent sense, of proteins. *See* Detergents; Fats.

SAPONIFICATION NUMBER. Alkalis hydrolyse fats to form salts (soaps) and glycerol, the amount required being known as the *saponification* (or soap forming) *number*. Usually about 5 g. of fat are refluxed with 50 ml. of $\frac{N}{2}$ KOH for $\frac{1}{2}$ hr. and the excess titrated with $\frac{N}{2}$ hydrochloric acid. The saponification number is the mg KOH required to saponify 1 g. fat.

Refs.: Williams, K. A.; Richmond.

SAPROPHYTES. In bacteriology this term is used to describe micro-organisms which lead a harmless non-parasitic existence in non-living materials. *See* Commensal organisms; Parasites.

SARCINA. An organism whose spherical cells are arranged in cubical packets of eight.

Types species: *S. lutea* the causative organism of "yellow spot" in milk bottles. *See* Bottle washing; Classification; Thermoduric bacteria.

Refs.: Bergey; Wilson and Miles.

SCARLET FEVER. *See* Diseases.

SCHARDINGER ENZYME. *See* Aldehyde reductase.

SCHERN-GORLI TEST. A test for heated milk based on the fact that if milk is heated above 58° C. the fat globules no longer adsorb colloidal particles of carmine, charcoal, etc. Unheated milk gives a coloured cream layer.

SCHOOL MILK. In this country virtually all school children receive $\frac{1}{3}$ pint milk daily while at school in special $\frac{1}{3}$ pint bottles. *See* Costings; Milk marketing; Nutritive value; Utilisation.

Ref.: Wright (1936), *An Enquiry into the Drinking Habits of Children of School Age, with Special Reference to Milk Drinking*, Hannah Dairy Research Institute.

SCHOTTE. Boiled clarified whey used for cheese starters and other cultures on the Continent.

SCOTLAND, DAIRYING IN. ***Structure of the Industry.*** *Production.* Dairying is one of Scotland's most important industries, and one which has made much progress during recent years. This is illustrated by the following figures:

PRODUCTION OF MILK

Year	*Million gal.*	*Percentage increase*
1939	134·1	
1949	171·3	29
1953	206·1	54

PRODUCTION OF SPECIALLY DESIGNATED MILK

Year	*Million gal.*	*Percentage increase*
1939	57·2	
1949	143·0	83
1953	189·1	123

Herds Producing "Certified" and/or "Tuberculin Tested" Milk

Year	*Number of herds*	*Percentage of total dairy herds*	*Million gal. of milk*
1939	1712	19·3	32·8
1949	6125	68·7	135·0
1953	7566	83·6	172·3

Milk sold off farms accounts for 27·4 per cent. of the total value of the output of the agricultural industry. The value of milk output has risen from £9 million in 1938-39 to £39·6 million in 1952-53.

Dairying is carried on primarily in the south-west of Scotland in an area covered by the counties of Dumfries, Kirkcudbright, Wigtown, Ayrshire, Lanark, Renfrew, Dunbarton, and Bute. These counties are admirably suited to dairying. The mild climate, the long grazing season and good pastures have encouraged farmers to practise dairying in these counties for many years. It is estimated that at least 46 per cent. of the milk supply of Scotland is produced in these counties.

During recent years, however, many of the large arable farms in the eastern counties of the country have undertaken dairying in preference to feeding stock, while still maintaining the arable character of their farms. This has no doubt been due to special conditions—demand for liquid milk and shortage of concentrated feeding stuffs—which became common during the war and post-war period. A similar swing over to dairying in these counties took place during the last 20 years of the nineteenth century when the effect of the importation of food from overseas began to be felt. At that time, however, many arable farmers were unable to alter their systems of farming sufficiently quickly to meet the needs of the new situation and vacated their farms. The thrifty peasant type of farmer in the south-western counties soon realised that there were opportunities for successful dairying in those once arable farms, and migrated east. So great was the migration that "Go east for a farm but west for a wife" became a Scottish saying of the time.

Dairying has also during recent years become a prominent feature of some of the northern counties, particularly Caithness and Orkney. Prior to 1946 there was little or no outlet for milk produced in these counties. The North of Scotland Milk Marketing Board, however, erected a creamery at Kirkwall in Orkney in July 1946, to manufacture cheese, and one at Wick in Caithness in April 1947 to pasteurise milk and despatch it to the south. The installation of these two creameries was a great stimulus to dairy farming. In 1946 the volume of milk produced in Orkney was 617,000 gal. and in Caithness 277,000 gal. By the end of 1953 production had risen to 1,570,000 gal. and 1,242,000 gal. respectively. The development of the Board's activities at Inverness also stimulated milk production in Moray and Nairn, where production has increased from 1,018,300 gal. in 1944 to 2,499,500 in 1953.

In addition to the 9043 registered producers in Scotland, there are some 20,000 farmers who keep one or more cows to supply milk for their own use and that of their workers and neighbours. About 80 million gal. of milk a year are produced on these farms, of which some 20 million gal. are used as liquid milk.

The average size of the dairy herds in Scotland is 31 and herds of 20 to 40 cows produce 43 per cent. of the total milk supply. Forty-four per cent. of the milk supply comes from herds with over 40 cows, of which 12 per cent. comes from herds with over 70 cows. Thirteen per cent. of the supply comes from herds with fewer than 20 cows. The ratio of large herds to small herds shows a wide variation from county to county. In Wigtown, for example, herds of over 50 cows are more common than in Ayrshire, Dumfries, Renfrew, and Lanark, where the herds average 25 cows. In the east, three-fourths of the dairy herds are under 30 cows, although the arable farmers who have recently turned over to dairying have installed large herds averaging over 50 cows. In the northern counties the herds are smaller and the majority average less than 20 cows. In the Western Isles many farmers keep only sufficient cows to supply milk for their own needs and those of their workers and neighbours, and consequently many families have difficulty in obtaining sufficient milk. Even those who keep cows may be without milk during the winter and early spring because of the insufficiency of winter feeding for the animals. To ease this difficulty in Stornoway the North of Scotland Milk Marketing Board now send each day about 1000 gal. of milk by rail and boat from Inverness, a distance of 100 miles. This shortage of milk is not confined solely to the Highlands and Islands, but extends to some of the large arable farms in the counties in the east. These farmers keep only sufficient cows to supply their own household, with the result that the workers have to depend on local retailers who are not anxious to distribute their milk over a wide and scattered area.

The Ayrshire breed is the most popular, but there are many herds of Friesian and Shorthorn; a few Jersey, Guernsey and Red Poll, and in Shetland, Shetland cows. The average milk yield per cow has increased from 620 gal. in 1945 to about 700 gal. in 1950, but there is still, however, a wide variation in the yields of individual herds. Some are as low as 400 gal. while others exceed 1000 gal. per cow per year.

Eradication of tuberculosis from dairy and other herds has made very satisfactory progress in Scotland during the last few years. The following counties have been declared attested areas under the Attested Herds Scheme of the Ministry of Agriculture: Ayr, Bute, Dumfries, Kirkcudbright, Renfrew, Wigtown, and Zetland, also a portion of Argyll. The counties of Dunbarton, Lanark, Peebles and Stirling are now scheduled for eradication, and a number of other counties have been declared free testing areas, in whole or in part. From this it follows that in most of the above counties all herds whether producing Certified or Tuberculin Tested milk or non-designated milk are attested. Of the total number of registered dairy herds in the country 94·1 per cent. were attested at the end of 1953.

Most dairy farmers in Scotland house their cows in cow-sheds, or " byres " as they are termed, but those who have recently undertaken dairying in arable counties of the east have in most cases adopted the cattle-court-milking-parlour system. As no suitable byres existed on many of these farms, the farmers considered it more economical to convert their feeding courts into cow-courts and erect a milking parlour, milk room and dairy scullery, or convert an existing building for this purpose. This arrangement is particularly suitable to the arable-dairy farmer, as it allows him to dispose of his straw and provides him with the much needed farmyard manure for his arable crops. It also helps to solve the difficulty of obtaining labour for milking and leaves him in the position to revert easily and quickly to stock feeding if and when he considers it desirable to do so.

The high standard of construction of the byres, cattle-courts and dairy premises in all the main dairying counties, is a feature worthy of special note. During the last ten years most producers who now hold licences to produce designated milk have reconditioned their byres and dairy premises. In the byres they have introduced wide manure channels, often as wide as 30 in., and improved both the inlet and outlet ventilation. A number of new byres have been built on the cantilever system which eliminates the use of trusses and other dust bearing surfaces. They have also installed steam sterilising equipment, and in some cases mechanical coolers. The methods of milk production, particularly on these farms producing designated milk, are also of a high standard.

Distribution. The consumption of milk in Scotland has risen from 250,000 gal. a day in 1939 to 360,000 gal. a day in 1953. This represents a rise in the consumption of milk from 0·4 to 0·6 of a pint per day per head of the population.

To supply the large centres of population, Glasgow, Edinburgh, Dundee, and Aberdeen, milk has to be brought some distance from the dairying areas. Milk supplied to Glasgow is drawn largely from the counties in the south-west, that of Edinburgh from Dumfriesshire, Lanarkshire and the counties adjacent to the city, while Dundee obtains its milk partly from the counties of Kincardine, Perth and Angus, and partly from the south-west. Aberdeen obtains its milk from the county of Aberdeen, which also exports milk to Dundee and Edinburgh at certain times of the year.

The milk is collected from the farms and taken to creameries owned by the Milk Marketing Boards and private companies such as the S.C.W.S., United Dairies and Northern Wholesale Dairies, Ltd. It is then despatched in cans or tankers to the cities, where it is often pasteurised and distributed from the companies' own city dairies or smaller retail purveyors. In the smaller towns milk is distributed by producer-retailers and small dairy companies who handle locally produced milk and also by local Co-operative Societies, many of whom obtain their supplies from the S.C.W.S. creameries. During the last five years there has been a considerable reduction in the number of producer-retailers and small dairymen handling bulk milk in the south of Scotland.

In the northern counties, Inverness, Moray, and Nairn and the counties farther north, most of the retail milk trade is undertaken by the North of Scotland Milk Marketing Board, which distributes milk over a wide area from its depots in Inverness, Dingwall, Golspie, Wick, and Nairn.

Pasteurisation and heat-treatment of milk in Scotland have developed considerably during recent years. It is estimated that 76 per cent. of the milk sold to the public in Scotland, and at least 95 per cent. of the milk sold in the four large cities, is pasteurised. At the end of 1953 there were 136 licenced pasteurisation plants. The majority of these plants are of the high-temperature-short-time type. Local authorities sample the milk from these plants at least once a fortnight, and a very high percentage of the samples comply with the statutory standards.

Manufacture. Some 30 years ago most of the milk produced on the farms in Dumfriesshire, Wigtown, Kirkcudbright and South Ayrshire was manufactured into cheese on the farms, but after the introduction of the Scottish Milk Marketing Board this practice was rapidly given up. Most of the cheese produced in Scotland is now made at the Milk Marketing Board's creameries (six in number) in Kirkcudbright, Wigtown and Orkney, and at creameries owned by S.C.W.S. and United Dairies. Condensed milk is manufactured at General Milk Products Factory at Dumfries, at Nestle's Milk Factory at Dunragit in Wigtownshire, and at United Dairies Creamery, Kirkmichael, Ayrshire. These firms together handle up to 200,000 gal. of milk a day at the peak period of production. The factories are fitted with the most modern equipment and facilities. Spray-dried milk powder is manufactured at the Scottish Milk Powder factories at Kirkcudbright and Mauchline. Both factories have installed up to date equipment for processing and packing the milk.

Milk Marketing Boards. There are three Milk Marketing Boards in Scotland, namely, the Scottish Milk Marketing Board which covers the counties south of the Grampians, the Aberdeen Milk Marketing Board for the Counties of Aberdeen, Kincardine and Banff, and the North of Scotland Milk Marketing Board for the counties of Inverness, Ross and Cromarty, Sutherland, Caithness, Moray and Nairn, and Orkney. The position is, therefore, different from that in England and Wales, where there is only one Milk Marketing Board. The origin of the three Scottish Milk Marketing Boards is interesting. When the control exercised by the Ministry of Food ended in 1920, the financial position of the producer again became unsatisfactory. The difference in the price which he received for his milk from the distributor and that paid by the consumer to the distributor gradually widened. It became only too clear that this unsatisfactory position could not continue as the price which the producer received was almost uneconomic. In an attempt to ease the position a Joint Milk Council was formed, but during its operation some producers in the West, who were dissatisfied with the steadily widening margin between the retail price of milk and that which they as producers received, formed themselves in 1927 into an association for the marketing of milk supplying the Glasgow market. This association was known as the Scottish Milk Agency or Scottish Milk Pool, and was the first large-scale Milk Marketing organisation to be started in Great Britain on a voluntary co-operative basis. During the first year of its operation the Agency was so successful that a Branch was established in Aberdeen. For various reasons, however, during the third and fourth years in the life of the Agency, an increasing number of members resigned from the parent body and arranged contracts privately with distributors. The result was that the Agency became ineffective as a marketing body. The Branch in Aberdeen, however, continued to operate successfully and became autonomous.

The depressed state of the agricultural industry, the failure of the Joint Milk Council and the Scottish Milk Agency, created a serious position for the dairy farmers. So serious did that position become that producers in areas remote from a consuming centre, for example, Wigtown, were having to accept from distributors as little as 4d. and 6d. a gal. for their milk, and in addition had to bear the cost of transport. In an attempt to prevent the collapse of the dairy industry Parliament passed the Agricultural Marketing Act in 1931. One of the provisions of the Act gave powers for the appointment of a re-organisation Committee to prepare a scheme for regulating the marketing of milk. It was on the basis of this report that producers' Milk Marketing Boards were established both in England and Scotland. During the discussions on the formation of the Boards the producers in Aberdeen and Kincardine were doubtful, as a result of their previous experience with the Scottish Milk Agency and the large surplus of milk in the south of Scotland, about co-operating with their fellow producers in the south of Scotland, and decided to form their own Milk Marketing Board and to control their own finances, thus leaving those producers south of the Grampians to form their own organisation. In the North of Scotland the counties of Inverness, Ross and Cromarty, Sutherland and Caithness decided for various reasons not to join either the producers in the south or those in Aberdeen and Kincardine, but to form their own Milk Marketing Board. The producers in Banff, Moray and Nairn, Orkney and Shetland and part of Argyll voted to remain outside a Milk Marketing scheme, as they were primarily producer-retailers, and could see no advantage in becoming members of a Milk Marketing Board. Thus, three Milk Marketing Boards were formed, namely the " Scottish ", the " Aberdeen ", and the " North of Scotland ".

The Scottish Milk Marketing Board was formed in May 1934, and now includes Argyll and the area south of the Grampians. All producers in the area holding a Certificate of Registration from the local authority are required to sell all their milk to or through the agency of the Board and to abide by the conditions laid down in the Board's contract. There are 7885 producers in this Board's area.

Since the Board commenced operations the annual sales of milk off farms have increased from 109 million gal. to 174·5 million gal. a year and payments to producers have risen from £3·8 million to £32·75 million a year in 1953. In December 1953, 98 per cent. of the milk produced in the area of the Scottish Marketing Board was obtained from herds which had passed the tuberculin test. Five and three-quarter million gal. was sold as " Certified " milk. Sales of liquid milk to or through the Board in 1953 amounted to approximately 180 million gal., an increase of some 50 per cent. compared with those in the year 1939. In 1939, 43·8 million gal. of milk was used for manufacture which represented 36·6 per cent. of the total production. In each following years the proportions became gradually less, and in 1947 only 17·7 million gal. was manufactured, that is 14 per cent., but in 1953 the proportion had risen to 60 million gal. or 35 per cent. During this period 1939 to 1953 a decreasing amount of milk was manufactured into cheese on the farms. In 1939, 6·5 million gal. was so used, and in 1953 1·4 million gal. The average price per gal. (excluding bonuses), received by producers in 1939 was 10·37d. This has steadily increased to 29·08d. in 1950 and 34·77d. in 1953.

With a view to improving the dairy herds in the country, the Scottish Milk Marketing Board have recently set up an artificial insemination centre at Southbar in Renfrewshire with which are associated 7 sub-centres.

The Aberdeen Milk Marketing Board was established in 1934, and now includes the counties of Aberdeen, Kincardine and Banff. There are (December 1953) 667 producers in the Board's area, of whom 483 hold licences for production of " Certified " or " Tuberculin Tested " milk. 82·1 per cent. of the milk sold to or through the Board is from herds which have passed the tuberculin test. The Board has one creamery in Aberdeen at which milk is pasteurised and sold by wholesale to distributors in Aberdeen, Dundee and Edinburgh. Surplus milk is sent to the Scottish Milk Marketing Board for resale or manufacture.

In the North of Scotland Milk Marketing Board's area the number of producers is (at December 1953) 478, of which 327 hold licences for the production of " Certified " or " Tuberculin Tested " milk. Approximately 83·9 per cent. of the milk sold to or through the Board is from tuberculin tested herds. The Board has depots at Wick, Inverness, Dingwall, Golspie and Nairn from which they distribute " Pasteurised ", " Certified " and " Tuberculin Tested " milk chiefly by retail over a wide area. Almost all of the milk produced in Orkney is manufactured at the Board's creamery at Kirkwall.

As in the case of the main Scottish Board all registered producers in both the Aberdeen and North of Scotland Milk Marketing Board's areas are required to sell all their milk to or through the agency of the Board. A number of producers in the Western Isles have been exempted from the provisions of the North of Scotland Milk Marketing Board, primarily for geographical reasons.

Administrative aspects. The administration of the Acts and Orders relating to the production, handling, processing and distribution of milk in Scotland is a function of the local authorities of the counties and large burghs (that is, burghs with a population of over 20,000). The Secretary of State for Scotland has an immediate interest in the administration and discharges his functions through the Department of Health for Scotland. The Department have a staff of milk inspectors who are located in different parts of the country and have the duty of advising local authority officials on milk and dairies administration. The local authorities have, in addition to their sanitary staff, a staff of milk officers qualified in dairying who visit farms and dairy premises and give guidance to dairymen on questions relating to hygiene of milk production and distribution. The arrangements in Scotland are therefore fundamentally different from those in England, where the administration of the Regulations relating to the hygienic production of milk is carried out by the Ministry of Agriculture and those relating to distribution by the local authorities.

The early legislation governing the production and distribution of milk was replaced by the Milk and Dairies (Scotland) Act, 1914. Because of the war of 1914-18 and the difficulties of the immediate post-war period, the coming into operation of the Act was postponed until 1925. It is now the principal statute regulating milk and dairies administration in Scotland. The definition of a " dairy " under the Act expressly excludes " premises from which a person sells milk only in small quantities and for their own consumption to persons in his employment or to neighbours ". Such dairies are known as " exempted " premises.

The Act provides, amongst other things, for the inspection of all dairies at least once a year by an official of the local authority, the registration of all dairymen and the making and enforcement of dairy by-laws by local authorities. In addition, the Act gives powers to the Secretary of State to make general or special orders for the protection of milk against infection or contamination, the prohibition of the addition of colouring matter to milk, the conveyance of milk, sealing and labelling of cans, etc.

Pending the coming into operation of the Act of 1914, the Milk and Dairies (Amendment) Act, 1922, was introduced. It required local authorities to keep a separate register of retailers of milk, it prohibited the addition of colouring matter to milk, the sale of tuberculous milk, and it empowered the making of Orders authorising the use of special designations in relation to milk.

In 1934 the Milk and Dairies (Scotland) Order, 1934, was made under the Act of 1914. It provided additional requirements for the protection against infection and contamination of milk and for the hygienic conveyance of milk, including the sealing and labelling of milk cans transported by common carrier or other person.

The Milk (Special Designations) (Scotland) Order, 1951, which consolidates and replaces the Orders of 1936 to 1949, provides for the use of special designations in relation to milk and for the granting of licences by local authorities authorising dairymen to use such designations. The issue of licences and the administration of the Orders are functions of the local authorities of the counties and large burghs. A dairyman has, however, the right to appeal to the Secretary of State against the refusal of a local authority to grant or to continue a licence to sell specially designated milk. The designations prescribed are " Certified ", " Tuberculin-Tested ", " Standard ", " Pasteurised " and " Sterilised ". The use of the designation " Standard " terminates at end of September 1954. After September 1954, " Certified " and " Tuberclin Tested " licences will only be granted to producers if the herd is " attested ". The conditions which a dairyman has to comply with in respect of such licences are detailed in the Order. They refer to the health of the animals, the handling of the milk, the suitability of equipment and statutory standards. The statutory standards with which samples of milk taken at any time before delivery to the consumer must comply are as follows: " Certified " milk (that is " Tuberculin-Tested " milk bottled on the premises at which it is produced, namely the farm)—bacterial count not to exceed 30,000 per ml. and no coliform bacteria in one 10th ml.; " Tuberculin Tested " and " Standard milk "—bacterial count not to exceed 200,000 per ml. and no coliform bacteria in one 100th ml.; Pasteurised milk—not to exceed 2·3 L.B.U. when tested by the phosphatase test, and not to contain coliforms in one 100th ml.; " Sterilised " milk has to satisfy a " Turbidity" test.

Food and Drugs (Adulteration) Act, 1928, and Sale of Milk Regulations, 1901. The Food and Drugs (Adulteration) Act, 1928, provides (Sect. 2) that no person shall sell to the prejudice of the purchaser any article of food which is not of the nature, substance or quality of the article demanded by the purchaser, and gives powers (Sect. 16) to " sampling officers " to purchase or to take any sample of any food. The Sale of Milk Regulations, 1901, provide that where a sample of milk contains less than 3 per cent. of milk fat or less than 8·5 per cent. of other solids, it shall be presumed, until the contrary is proved, that the milk is not genuine. The adoption of a presumptive standard was found to be necessary because (*a*) of the wide variations which were known to occur in the composition of genuine milk, and (*b*) no method was available for determining with any degree of certainty that milk had been adulterated by the addition of water or whether milk fat had been abstracted. So far as milk is concerned the Food and Drugs Act, 1938, does not apply to Scotland.

Scottish Milk Testing Scheme. The scheme which came into operation in 1946 provides for the weekly routine sampling and testing for keeping quality of all milk supplies arriving at and leaving distributors' premises. It is concerned primarily with establishments handling over 500 gal. of milk a day but it includes a number of smaller distributors. Supplies of milk which when tested by the " compensated " resazurin test (that is, compensated to take into account the atmospheric shade temperature prevailing when the samples were taken (*see* Resazurin tests)) give a disk reading of 3½ or less are considered to be substandard and in need of improvement. The results of the tests on such supplies are sent by the distributor to the local authority from whose area supplies are obtained. The milk officer or other representative of the local authority then visits the farms concerned with a view to securing improvement of the supplies. Milk leaving distributors premises is tested by a methylene blue test. Supervision of the general working of the scheme is undertaken by the inspectors of the Department of Health. Any distributor desiring to operate within the scheme has to secure the Department's approval of his laboratory and testing staff. The scheme is making very satisfactory progress and is doing much to improve the keeping quality of milk supplies.

Refs.: *News Letters*, Scottish Milk Marketing Board, 95 Bothwell Street, Glasgow; *Annual Report of the Department of Health for Scotland*, H.M.S.O., London; *Scottish Agricultural Economics*, Vol. IV, Department of Agriculture for Scotland, H.M.S.O., London; *Scottish Milk Testing Scheme*, Memo. No. 9/46 (revised 1950) Department of Health for Scotland, H.M.S.O., London.

SCRUTINEERS. Dairy operatives who examine washed bottles for faults. (Fig. Sc 1.)

Ref.: Davis and Bell (1954), *DI*, **19.** (In Press.)

SCURVY. A deficiency disease due to lack of vitamin C. *See* Nutritive values; Vitamins.

SECRETIN. A hormone produced in the intestine which controls the secretion of the pancreatic juices or enzymes. *See* Hormones.

SECRETION. This metabolic process may be defined as the synthesis and liberation of chemical substances from glands. *See* Milk secretion.

SEDIMENT TEST. A test for visible dirt in milk in which ⅓, ½, or 1 pint of milk is forced through a pad or disk of cotton wool. Alternatively a certain volume may be centrifuged and the deposit measured volumetrically. This test has no correlation with bacteriological quality because ordinary dirt, soil, gravel, hair, pus cells, etc., have little or no effect *as such* on keeping quality. *See* Bacteriological grading; Clean milk production; Routine tests.

Refs.: Soc. Pub. Anal. (1937), *A*, **62**, 287; B.S. 736 (1937); *Milk testing*; Richmond.

SEGELCKE AND STORCH'S LAW. *See* Rennet.

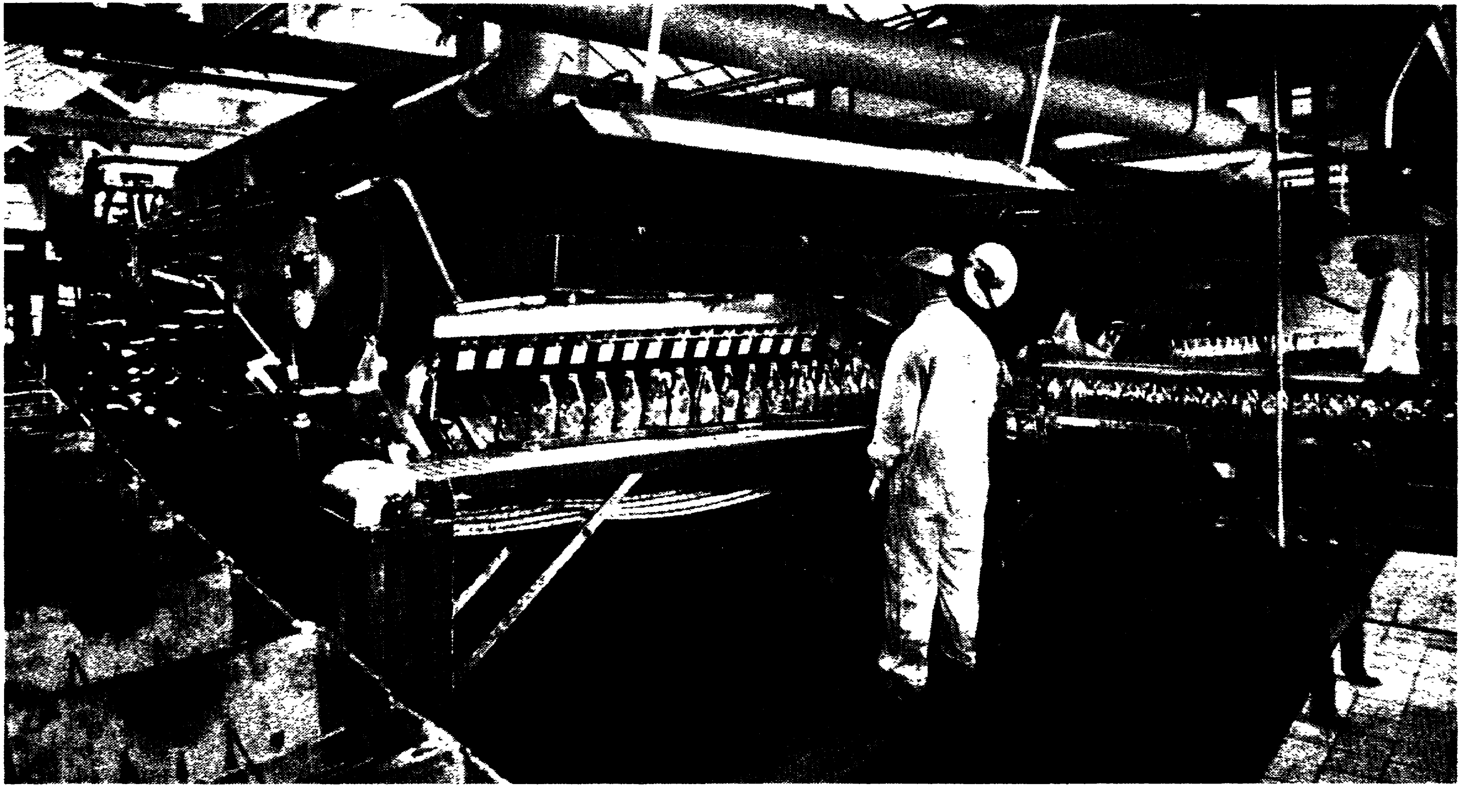
SENN PROCESS. *See* Butter-making machines.

SEPARATED MILK, MACHINE SKIMMED MILK. Milk from which nearly all the fat has been removed by skimming or separating. The amount of fat left depends on the type, speed, and setting of the separator, but usually it is about 0·1 per cent. and moreover consists of the smallest size fat globules so that this small amount of fat does not rise. *See* Butter; Composition; Condensed milk; Cream; Nutritive value; Pigs.

ESPARATOR. The cream separator is virtually a series of conical plates which revolve in a bowl at high speed and fling the debris of milk outwards and the fat being the lightest fraction collects in the centre from which it is collected and led out.

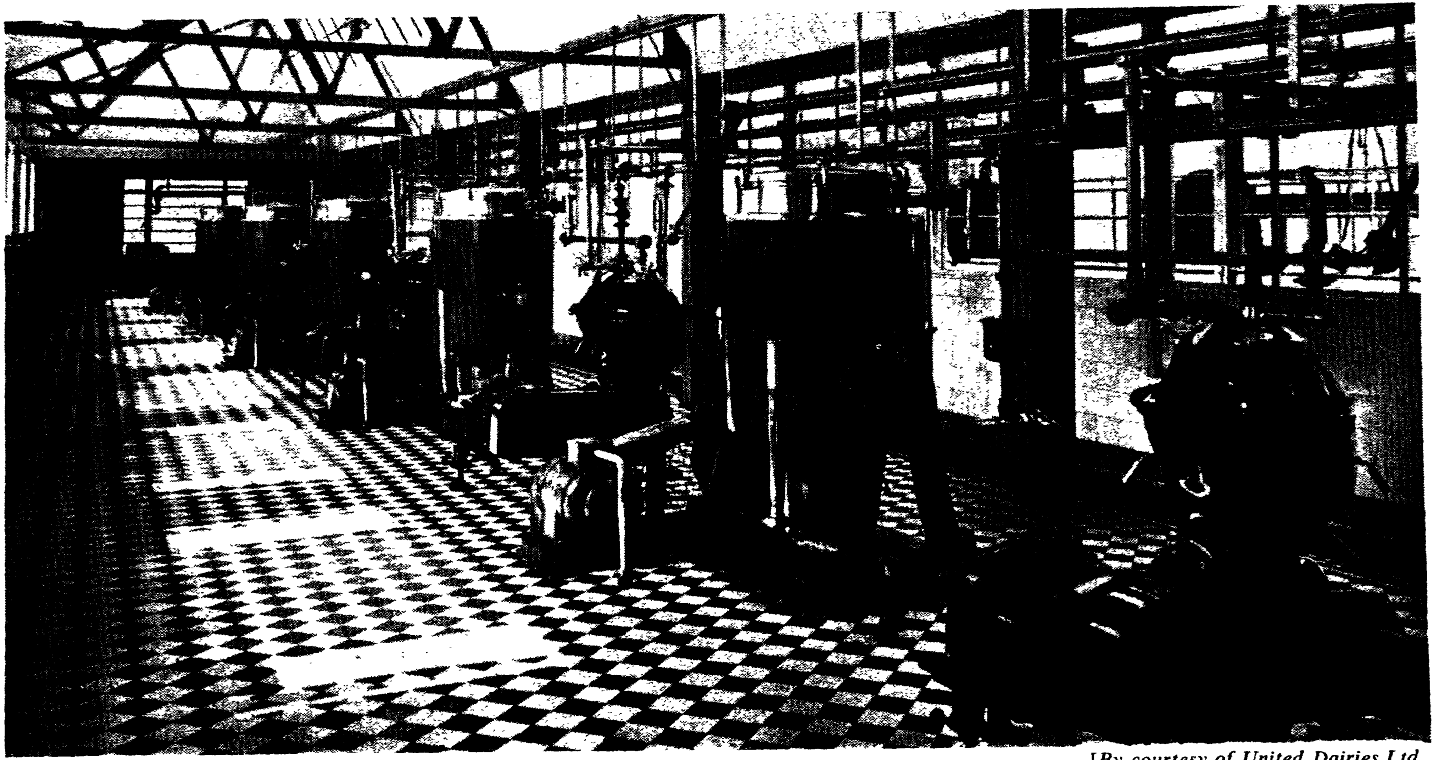
Fig. Sc 1 shows a battery of separators and pre-heaters in a modern factory. *See* Butter; Cream; Cream line; Management of creameries.

Refs.: Farrall; Richmond; Rogers; Schmitz and Schmitz (1951), *M*, **6**, 195; Schmitz (1950), *M*, **5**, 418; Wilsmann (1948), *M*, **3**, 302, 327, 366.



[*By courtesy of United Dairies Ltd*

FIG. Sc 1.—*The Scrutinising of Washed Bottles.*



[*By courtesy of United Dairies Ltd.*

FIG. Se 1.—*Power Separators and Preheaters in a Modern Factory.*

SEPARATOR SLIME. The visible dirt, cell debris, etc., which is separated in skimming milk. It contains 18 to 26 per cent. protein, 2·5 to 3·5 per cent. " ash ", 0·5 to 3 per cent. fat., 2 to 8 per cent. " other organic matter ", and is, in effect, a concentrate of the heavier than sp. gr. 1·035 substances in milk. Due to the high content of cells and bacteria it is very rich in enzymes. *See* Clarification.

SEPSIS. Contamination or poisoning by pathogenic bacteria.

SEPTIC SORE THROAT. An infection caused by α- and β-haemolytic streptococci. *See* Diseases.

SEPTICAEMIA. Infection of the blood by pathogenic bacteria.

SERRATIA. A genus of red pigment-forming, Gram-negative, non-spore forming, lactose-fermenting, gas-forming rods. Biochemically they resemble the coliforms (p. 262).

Type species: *Serratia marcescens* (*Bacillus prodigiosus*) whose growth on bread may have been the origin of the " bleeding host ". *See* Classification.

Ref.: Bergey.

SERUM. The clear liquid left from blood when the red and white corpuscles have been removed by clotting or dialysis.

Serum is valuable as a nutrient medium for the more fastidious pathogenic bacteria. The clear fraction of milk is sometimes known as *milk serum*. *See* Media.

SERUM BUTTER. Butter made from the fat of whey or milk serum.

SESAME OIL. A fixed or non-volatile oil from *Sesamum indicum* which has been used for the adulteration of butterfat.

Ref.: Williams, K. A.

SEXUAL EXCITEMENT. *See* Composition, factors affecting; Hormones; Milk secretion.

SHEEP GHEE. Dehydrated fat from sheep milk. *See* Ghee.

SHEEP MILK. *See* Mammals.

SHERBETS. *See* Ice cream.

" SHOCKING ". A trade term applied to a heat treatment less than that equivalent to pasteurisation but sufficient to kill or " shock " a large proportion of the organisms present and so improve keeping quality or allow specially added cultures to predominate. *See* Cheese, p. 168 ; Pasteurisation.

SHOMAR (or SUPERVISOR). The Jewish official who supervises the production and handling of special milk for Jews such as Kosher (p. 567) and Kedassia.

SHORTHORN. *See* Breeding.

Refs.: Burrows (1950), *History of Dairy Shorthorn Cattle*, London; Marson (1938), *Scotland. The World's Stud Shorthorn Farm*, Edinburgh; Sinclair (1908), *History of Shorthorn Cattle*, London.

" SHOWING ". Entering dairy cows or other stock at shows organised by the B.D.F.A., etc. *See* Breeding; Management of dairy cattle.

SILICA GEL MEDIA.

Ref.: Taylor (1950), *JGM*, **4**, 235.

SILAGE. Silage-making is the preservation of grass and other green foodstuffs for cattle by holding it in a moist acid condition $p\text{H}$ 3 to 4. The acid may be produced by the natural fermentation of added molasses or may be added as hydrochloric acid as in the A.I.V. process (named after A. I. Virtanen the Finnish biochemist). Silage is fairly common in northern Europe but has not been extensively adopted in this country, probably because of bad technique in the earliest attempts. *See* Agriculture; Feeding; Grass.

Refs.: Barnett (1954), *Silage fermentation*, London ; Watson and Smith (1951), *Silage*, London ; Watson (1939), *The Science and Practice of Conservation*, London ; Virtanen (1938), *Cattle Fodder and Human Nutrition*, Cambridge; Watson (1938), *Silage and Crop Preservation*, London ; Cunningham and Smith (1940), *JDR*, **11**, 243 (microflora of mineral acid silage).

SILO. A chamber for making silage. It usually consists of a round tower made of concrete. Prefabricated silos can be obtained, and in these concrete slabs are held together by cable.

SINGLE CREAM CHEESE. *See* Cheese, p. 200.

SIRE. The father of an animal. With dairy cows the bull has an important effect on the milk of his daughters, particularly the butterfat content. *See* Breeding.

SKIM MILK, SKIMMED MILK. This term strictly should be reserved for milk from which the fat has been " skimmed " by allowing it to rise naturally, but separated milk is commonly referred to as " skim milk ". *See* Condensed milk ; Cream ; Pigs; Separated milk.

SKIN FORMATION ON MILK. Even in the cold there is an invisible " skin " on milk as substances such as the water-soluble proteins, lipids, etc., will tend to concentrate on the surface. Heating milk to temperatures of about 60° C. and over causes a visible skin to form. This consists of precipitated albumin and globulin, calcium phosphate, casein, and fat, the last very variable.

Ref. : Rogers.

SKUTA. An alcoholic fermented whey made from sheep's milk in the Carpathians.

SKYR. An Icelandic soured milk.

Ref. : Pétursson (1949), *IDC*, 3, 419.

" SLEEPY CREAM ". Cream which will not churn in the ordinary time, usually on account of alkalinity or low acidity. *See* Butter.

SLIMY MILK. A synonym for ropy milk (p. 932).

SLOW STARTER. *See* Starters.

SMELL. This sensation is produced in the olfactory centre of the brain by nerve impulses caused by the impact of molecules on the peripheral end of the olfactory nerve in the nose. It is possible that single molecules can cause the sensation of smell. *See* Butter; Cheese; Flavours; Milk powder; Platform testing.

Refs. : Parker (1922), *Taste, Smell and Allied Senses*, New York ; Moncrieff (1951), *The Chemical Senses*, London.

SOAP. A compound of a fatty acid with a base. Sodium stearate is hard soap ; sodium oleate soft soap. *See* Detergents.

SOAPY TASTE. A soapy taste in dairy products is usually due to lipolysis (giving free fatty acids) and an alkaline reaction.

SOCIETY OF PUBLIC ANALYSTS METHODS. The Milk Products Subcommittee of this society have published valuable reports on analytical methods for dairy products. *See* Condensed and evaporated milk ; Milk powder.

Ref. : Richmond.

SODIUM. The commonest member of the alkali-metal group, lithium, sodium, potassium, etc. A powerful alkali, it is one of the chief factors on the alkaline side in controlling the acid-base balance in milk, the others being potassium and calcium. The sodium content of milk rises in mastitis and late lactation. *See* Abnormal milk ; Constituents ; Mastitis.

SODIUM CARBONATE, HYDROXIDE, PHOSPHATE, SILICATE. *See* Detergents.

SOFT CHEESE. *See* Cheese, p. 200. Soft cheese was formerly defined by the Ministry of Food as containing more than 55 per cent. moisture and the maximum price was 1s. 1d. per lb.

The Order was repealed in the 1950 Cheese Order (S.I. 1069) and the 1950 Cheese Amendment Order (S.I. 279). Soft cheese is now free from any control of standard or price. However, care must be taken that any product offered for sale complies with the Labelling of Food Order 1953 (S.I. 536) and the Defence (Sale of Food) Regulations 1943.

SOFT CURD MILK. This may be defined as milk which, when treated with rennet, does not give a firm clot. Persons with defective or inadequate gastric juices may find ordinary milk difficult to digest, hence the vogue for soft curd milk, especially in America. As the firmness of clot is controlled by acidity, the condition of the proteins and soluble calcium, it follows that reducing the acidity or soluble calcium and changing the physical state of the proteins will turn a normal milk into a soft curd milk. The simplest way to achieve one of these things is to add sodium bicarbonate $NaHCO_3$ or to heat the milk. Some cows naturally secrete soft curd milk so that selection of cows can also achieve this object. *See* Curd tension.

Ref.: Rogers.

SOL. A colloid " dissolved " in water in colloidal solution. Albumin and globulin in milk and whey are examples of a sol ; heat may convert them into a gel form.

SOLIDS. A term applied to all the solid matter in milk, soluble, colloidal and in suspension or present as an emulsion. *See* Constituents ; Total solids.

" SOLIDS." A colloquial term in the dairy industry for the solids-not-fat. *See* Milk solids.

SOLIDS-NOT-FAT. This term includes everything in milk except the fatty matter (fats and lipids) ; the cells and bacteria are usually not of gravimetric significance.

The legal presumptive standard is 8·5 per cent. and milk below this limit is suspected of containing added water. However, genuine milk can be below 8·5 per cent. through (i) mastitis ; (ii) individuality of the cow ; (iii) breeding ; (iv) seasonal effect ; (v) poor feeding.

It has been asserted that the solids-not-fat value of our average bulk milk has been falling steadily over the last 20 years.

During recent years attention has been directed to the large proportion of herd supplies coming into creameries which are below the legal presumptive limit of the 8·5 per cent. solids-not-fat. During and since the war this has been most noticeable in late winter and early spring.

It has, however, been recognised for over 50 years that cows may secrete milk which has less than 8·5 per cent. solids-not-fat, and evidence for this has been published by Richmond and Tocher (1925), and a most useful summary of this particular problem is given in Bibby's *Book of Milk*.

This problem was fully recognised by the Wenlock Committee and the Sale of Milk Regulations (1901) recognised the so-called " appeal to the cow " test which was designed to prevent the unjust conviction of a dairy farmer whose cows happened to produce milk low in solids-not-fat. The " appeal to the cow " test was, in fact, suggested many years earlier by a magistrate, and was immediately put into use by some public analysts.

With the state of scientific knowledge at the time this was undoubtedly a most useful measure because there was no test which could detect adulteration with any degree of accuracy. Thus at that time added water could probably only be detected when present to the extent of 10 per cent. or more.

The reasons for cows secreting milk low in solids-not-fat were but little understood in 1901. Presumably there was no trouble due to seasonal variations in concentrates and other artificial foods at that time as cows would have been fed almost entirely on grass and hay supplemented by other home-grown crops. However, sub-clinical mastitis which is now recognised to be a considerable predisposing factor to low solids-not-fat in certain herds, was not recognised at this time, and this factor was ignored in papers on the subject until about 1930.

Cranfield *et al.* (1927) found that 16 per cent. of herd samples were below 8·5 per cent. S.N.F. in 1923-25, and Burr (1939) found that 13 per cent. in 1934 and 9 per cent. in 1935 fell below this standard. During and since the war this has been most noticeable in late winter and early spring.

Rowland (1944) reported that as many as 81 per cent. and 86 per cent. of samples at two creameries were below 8·5 S.N.F. at the times of lowest S.N.F. The S.N.F. values rose abruptly in May.

Although it was formerly commonly stated that feeding had no effect on solids-not-fat values, the shortage of concentrates during the war resulted in renewed investigation of this problem, and it is now accepted that low protein and especially low calorie intake can result in low S.N.F. values (Rowland 1946, 1948; Bartlett and Kay 1950; Kay (1947, *JRSI.* **67**, 515) suggests that breeding for volume without regard to quality, and inadequate feeding are the two most important factors. In one experiment where the protein was maintained at the normal level but the energy value reduced to 75 per cent. of the normal, the S.N.F. was reduced from 8·68 to 8·34 per cent. in 5 weeks. When the energy value was normal but the protein content reduced to 60 per cent. the S.N.F. fell from 8·68 to 8·50 per cent. and the protein fell from 3·07 to 2·95 per cent. It is, therefore, reasonable to conclude that the main causes for the fall in S.N.F. have been the acute shortage of imported concentrates and the poor quality of the hay. The increase in winter milk production is also a factor. The effects of season and feeding cannot easily be separated but Featherstone *et al.* (1951) have shown that it is possible for a herd which is efficiently managed and well fed to give low S.N.F. values in late winter and early spring.

Davis (1952) has summarised evidence from public analysts' samples from 1900 onwards. These suggest a significant fall in S.N.F. from about 1925 onwards.

See Abnormal milk; Average composition; Composition, factors, affecting; Constituents; Lactometer; Mastitis; Quality payment; Richmond's formula; Total solids.

Refs.: Davies; Richmond; Bailey (1952), *DSA*, **14**, 893; Roeder (1953), *M*, **8**, 125 (sources of error); Davis (1952), *A*, **77**, 499; Featherstone *et al.* (1951), *JDR*, **18**, 155; Bartlett and Kay (1950), *JRAS*, 87; Rowland (1948), *CI*, 106; Boden and Campbell (1942), *JDR*, **13**, 45 (determination by hydrometry); Rowland (1942), *CI*, p. 252; (1944), *JDR*, **13**, 261; (1946), *DI*, **11**, 656; Cranfield *et al.* (1927); Tocher (1925), *Variations in the Composition of Milk*, H.M.S.O.; Burr (1939), M.Sc. Thesis, Reading; Rowland (1951), *N.A.A.S. Quart. Rev.*, No. 14, 47.

SOLUBILITY OF MILK POWDER. The "solubility" of milk powder is extraordinarily sensitive to the technique used in determining it and it is very difficult to get good agreement between laboratories. This is because: (i) the fat in whole milk powder is a complicating factor; (ii) the velocity of solution of the insoluble fraction exerts a great effect on the analytical figure.

The "solubility" may be determined at two temperatures, namely, at 20° and 50° C. The differences between these two values express the amount of "dry heat denaturation" of the proteins of dried milk. The following methods have been used.

(*a*) ***Marquardt method.*** One g. of dried milk is successively treated with water at 50° to 55° C. in a centrifuge tube until the liquid is water-clear. The residue is dried and weighed and termed the "insoluble fraction".

(*b*) In the ***Supplee*** method, the dissolved protein in the centrifuged reconstituted milk is determined. This value, expressed as a fraction of the total protein, gives the solubility. Seven parts of water and one of dried milk are reconstituted at 65° C. before centrifuging for 10 min. at 2000 r.p.m.

(*c*) ***Howatt and Wright's method.*** Two g. of dried milk and 20 ml. of water are stirred for 30 min. at 20° C., and the whole centrifuged for 15 min. at 3000 r.p.m. The ratio of total protein in equal volumes of milk before and after centrifuging gives the solubility at 20° C. Protein is precipitated at 70° C. in a final concentration of 4 per cent. trichloracetic acid.

Stirring at 50° C. for 30 min. before centrifuging and determining protein in a similar manner as with reconstitution at 20° C. gives the "total plus recoverable solubility" of the milk powder.

Extreme care must be exercised to obtain reproducibility between solubility tests, especially in the technique of reconstitution. The variable fat and moisture contents introduce further complications and Lampitt and Hughes describe solubility in terms of solids-not-fat as follows: 5 g. of powder are shaken for 3 min. with 38 ml. (for full cream) or 45 ml. (for skim milk powder) distilled water at 20° C. After centrifuging at 1500 r.p.m. for 3 min. in a tared tube, the fat is discarded and 5 ml. of the supernatant liquid tested for solids content. As much as possible of the liquid is then discarded, the residue weighed, and after transfer to a dish with distilled water, the remaining solids determined. This final weight is then corrected for the attached liquid and the solubility expressed by difference in terms of solids-not-fat. *See* Milk powder.

Refs.: Richmond; Howat *et al.* (1939), *JDR*, **10**, 498 (rapid test and effect of stirring); Howatt and Wright (1933), *JDR*, **4**, 265 (tests at 20° and 50° C.); Wright, (1932), *JDR*, **4**, 122 (in terms of protein); Soc. Publ. Anal., Milk Products Report No. 1 (1927), *A*, **52**, 402; Lampitt and Hughes (1924), *A*, **49**, 176.

SOLUBLE ASH. Of the 0·75 per cent. ash in milk, water will dissolve about 0·23 per cent. (chiefly NaCl, KCl, and a little phosphate) leaving about 0·52 per cent. as an insoluble residue (chiefly phosphates of calcium and magnesium containing also some potassium and sodium). *See* Ash; Constituents.

SOLUTE. Any substance dissolved in another.

SOLUTIONS. True solutions consist of a solute in a solvent. Thus in milk the lactose, sodium and potassium chloride, the "extractives" and some other salts are in true solution. Filtration causes no change in the composition of true solutions. *See* Constituents; Osmotic pressure.

SOLVENT. Any substance which dissolves another substance.

SORCERERS' MILK. The mammary secretion of newly-born mammals.

SORE THROAT. *See* Diseases; Haemolytic streptococci; Septic sore throat.

SOUR MILK. There is no definition of sour milk or any hard and fast standard for the acidity at which milk becomes sour. The following values are typical:

	% "*Lactic acid*"
Fresh milk	0·14
Sourness detectable by smell . . .	0·18 to 0·20
Clot on boiling (due to souring) . .	0·24
Clot at 18° C. (room temperature) . .	0·60 or more

In practice it is impossible to be precise about souring because (i) smell is a subjective and variable test; (ii) souring is chemically a complex and variable process, producing not only lactic acid but also acetic, propionic and butyric acids, and carbon dioxide.

SOURING. The production of acid, chiefly lactic acid, by bacteria, chiefly lactic streptococci and coliform bacteria. *See* Acidity; Clean milk production; Coliforms; Lactic acid bacteria.

SOUTH AFRICA.

Refs.: Dept. Agric. (1949), *IDC*, **4**, 658; Corry (1949), *IDC*, **5**, 140 (S. Rhodesia).

SOUTH DEVON MILK. This is now sold on the same basis as Channel Islands at 1d. per pint extra. It must contain at least 4 per cent. fat.

SOW'S MILK. *See* Mammals.

SOXHLET-HENKEL (S-H) METHOD FOR TITRATABLE ACIDITY. This value is obtained by titrating 100 ml. of milk with $\frac{N}{4}$ NaOH. Normal milks give values about 7. Conversion to "per cent. lactic acid" is obtained by dividing by 44·4. *See* Acidity.

SOYA BEAN. A valuable animal feed, particularly rich in protein, fat, and phosphorus. *See* Feeding.

Ref.: Bowdidge (1935), *The Soya Bean*, Oxford.

SOYA BEAN MILK. A milky fluid prepared from soya beans.

SPAY. To remove the ovaries or castrate a female animal.

SPECIAL DESIGNATIONS ORDER. *See* Legal aspects; Milk Marketing; Milk (Special Designations) Order.

SPECIFIC GRAVITY. The specific gravity of a substance is the ratio of the weight of a volume to the weight of the same volume of water at 4°, 15·5° C. (60° F.) or some other specified temperature. For all practical purposes specific gravity is the same as density; in the Richmond formula (p. 932) specific gravity at 60° F. is used, but in the B.S.I. method density at 20° C. is used. It is essential to specify the temperature when discussing specific gravity as water and milk expand about 1 part in 1000 for every 5° C. or 9° F. change in temperature.

Specific Gravity of Dairy Products and Common Materials. Average values are:

Air	0·0012	Evaporated milk	1·066
Water	1·00	Cream (40 per cent.)	0·99
Water vapour (212° F.)	0·0006	Ice cream mix	1·08
Milk	1·032	Aluminium	2·56
Skim milk	1·035	Copper	8·94
Butterfat	0·9	Iron	7·86
Condensed milk	1·16		

See Density; Lactometer; Solids-not-fat.

Ref.: Richmond.

SPECIFIC HEAT. The specific heat of a substance is the amount of heat required to raise 1 g. 1° C. (calories), or 1 lb. 1° F. (British Thermal Units) at any stated temperature.

Average values in B.Th.U. per lb. are:

Air	0·243	Condensed milk	0·94
Water	1·00	Cream (40 per cent.)	0·68
Water vapour (212° F.)	0·47	Ice cream mix	0·80
Milk	0·935	Sugar	0·27
Skim milk	0·95	Aluminium	0·218
Butterfat	0·56	Copper	0·093
Cheddar cheese	0·64	Iron	0·119
Evaporated milk	0·92	Nickel	0·109

Ref.: Farrall.

SPHERE. Surface $4\pi r^2$; volume $4\pi r^3/3$.

SPHEROIDAL STATE. The condition of a globule of liquid cushioned by vapour on a hot surface.

SPHINCTER. A ring-shaped muscle closing an orifice. The teat of the cow is closed by a sphincter. *See* Milk secretion; Milking machines.

SPORES. Spores may be regarded as eggs or seeds of micro-organisms. In the bacteria two important genera of spore-forming organisms are known: (i) *Bacillus*—the aerobic sporeformers, *e.g. B. subtilis* or the hay bacillus. (ii) *Clostridium*—the anaerobic sporeformers, *e.g. Cl. butyricum*. *See* Bacillus; Classification; Clostridium; Stability; Sterilised milk; Thermoduric bacteria; Thermophilic bacteria.

Refs.: Wilson and Miles; Williams *et al.* (1952), *BR*, **16**, 89; Robinson (1951), *JGM*, **5**, 439 (structure); Knaysi (1943), *BR*, **12**, 19.

SPORULATION. The formation of spores.

SPRAY DRYING PROCESS. *See* Milk powder.

SPREADS. Dairy spreads are preparations resembling very soft cheese and butter in consistency and are prepared from any or all of the following: milk and whey solids, cheese (various), fats (various), emulsifying agents, vegetable and plant extracts or powder, seasoning, condiments and colouring matter.

Although resembling processed or pasteurised cheese they are invariably softer and are not always so drastically heat-treated. A typical formula is:

Cheddar cheese	60	Sodium citrate	2
Cream (40 per cent.)	20	Sodium chloride	0·5
Dried skim milk or whey	10	Water and other substances	7·5

Refs.: Whittier and Webb; Reinart and Brown (1953), *IDC,* **2,** 522.

SPRENGEL TUBE. This apparatus consists of a U-shaped tube with capillary ends at right angles. It is used for determining the specific gravity of milk (p. 962) the tube being weighed empty, filled with water and then with milk. The gravity is given by the ratio of weight of milk to that of water in the usual way. *See* Specific gravity.

SQUARE BOTTLES. These bottles are not perfectly square but have rounded corners. The chief advantages are (i) better packing of bottles and so stability in transport; (ii) economy of space not only in retail distribution but in the domestic refrigerator. It is reckoned that 6 square bottles can be accommodated in the same space as 4 round bottles; (iii) less weight (about 3 oz. on pint bottle).

Square bottles have now been introduced in this country but are only in use in a few dairies. They are more commonly used in America.

STAB CULTURES. A culture made by inserting a seeded platinum wire deep into a tube of agar or gelatine medium. Anaerobic, micro-aerophilic, and facultatively anaerobic micro-organisms will grow in the depth of the medium if the necessary nutrients are present.

STABBING CHEESE. *See* Cheese (Stilton), p. 201.

STABILISERS. Substances such as alginates, carageen (Irish moss), gelatine, which are used to stabilise emulsified foods. *See* Ice cream.

STABILITY TO HEAT. The ability of milk, evaporated milk, etc., to withstand heating without precipitation of constituents. *See* Acidity; Clot-on-boiling; Condensed milk. *Ref.:* Rogers

STABILITY, MICROBIOLOGICAL, OF DAIRY PRODUCTS. Cheese. For the purpose of this article, microbiological stability is defined as the resistance of dairy products to the growth of micro-organisms causing spoilage.

Casual consideration of the conditions under which cheese is manufactured would probably lead to the conclusion that the chances for and sources of contamination with micro-organisms are so great that it is surprising that any product, not dehydrated, of the very vulnerable basic material, milk, should possess any biological stability whatever. The milk used for cheese manufacture, produced and handled in the ordinary way of commerce, contains bacteria of many kinds and is subsequently handled in utensils and apparatus which themselves may contribute heavy contamination. Why is it, therefore, that well-made cheese of the so-called hard varieties, such as Cheddar or Parmesan, may be safely kept for comparatively long periods of time ?

The flora of milk itself may be, and often is, both varied and numerous. Lactic and other streptococci, coliform organisms of several types, aerobic and anaerobic spore formers, micrococci, *Achromobacterium*, yeasts and moulds and many others may be present. The rennet used in coagulating the milk may (but should not) contain anaerobes of peculiarly unpleasant potentialities and even the salt may not be free from micro-organisms. The starter, a culture of lactic streptococci, may also contain undesirable contaminants.

The foul and evil-smelling products of the rapid decomposition of injudiciously managed soft cheese of some varieties are examples of what may happen when things go wrong.

The secret of the remarkable biological stability of the hard cheese lies in the achievement, in the course of manufacture, of a set of conditions which provide, as nearly as possible, an absolute barrier to the growth of those micro-organisms which are incompatible with the qualities sought in the particular variety of cheese.

The cheesemaking season falls, traditionally, in the warmer part of the year, when milk is plentiful and milk for cheese is likely to contain a high bacterial population. Because milk contains a fermentable carbohydrate, lactose, together with the necessary nitrogenous substances for bacterial nutrition, and because milk as normally produced and handled acquires a generous inoculum of lactic streptococci, these will quickly predominate at favourable temperatures and the very fact that lactic acid is produced will tend, even in the milk, to suppress the more proteolytic types which attack the casein, with unpleasant consequences. The natural tendency for the formation of lactic acid in milk is the foundation stone of the stability of cheese.

Casein is coagulated by the enzyme of rennet, rennin, but it is very necessary, to secure a coagulum of the right type, to add rennet *only* after the correct acidity has been generated in the milk. This is usually ensured by an active starter, *i.e.* a culture of lactic streptococci with the property of rapidly resuming growth when added, in culture at the rate of rather less than 1 per cent. by volume, to milk in the cheese vat. This results in an overwhelming numerical superiority of those organisms which can ferment lactose, with the production of lactic acid, with minute quantities only of the other products of carbohydrate fermentation. Their growth is favoured at this stage by adjusting the temperature of the milk to about 84° F. When the *p*H has reached about 6·4 rennet is added, and coagulation takes place rapidly throughout the whole mass.

Then follows, after firm coagulation has occurred, a step most important for the future stability of the curd. The latter is cut into small ¼ in. cubes. Whey is thus released and the curd floats in a slightly acid pabulum. All the time the growth of the lactic acid organisms continues and the acidity rises slowly. The temperature of the whole mass is now raised from about 86° F. to about 102° F., in some varieties considerably higher. (A bacteriological examination at this stage should reveal only insignificant numbers of organisms other than lactic streptococci.)

The rise in temperature promotes the expulsion of water from the pieces of curd, which now tend to sink. The process of contraction is enhanced by the continuing increase in acidity. A good starter must possess the remarkable property of being able to continue acid formation in spite of a considerable rise in temperature.

After this so-called " cooking " process, the whey is withdrawn and the curd allowed to settle and finally to mat together. This results in the further expulsion of moisture. Most of the lactose remaining is, of course, removed with the whey, but the curd still contains all the water and lactose necessary to support vigorous growth of the lactic streptococci, of which some 90 per cent. are retained in the curd. This process is encouraged by packing large slabs of curd together and keeping them warm. Their volume ensures the right conditions, and the large population of lactic streptococci ensures a continuing and vigorous fermentation. When the fermentation is deemed to have gone far enough the curd is broken into smaller particles by a mill, salt added, the whole packed into a mould and pressure applied. In this way still further moisture is expelled. After the necessary time in the mould the cheese are removed, fabric bandages applied to sides and tops, and the cheese taken to store for ripening. This is briefly the sequence of bacteriological and other events up to the beginning of the ripening period in the process of hard-cheese making, when things go according to plan.

But what happens when there are errors in the process ? The effect of a failure or partial failure in acid production, on the correct development of which good cheesemaking rests, must now be considered. Certain coliform organisms, *e.g. Bacterium aerogenes*, themselves vigorous fermenters of lactose under favourable conditions, are capable, in the event of sluggishness in the development of acidity by lactic streptococci, of rapid growth. They produce gas as well as acid, the latter not by any means exclusively lactic acid, and cause the curd to float, owing to the entrainment of gas. This causes physical difficulty in handling the curd and may result in completely spoiled cheese. The embarrassment may be overcome to some extent by subsequent resumption of the initiative by the lactic streptococci but the resulting cheese are seldom of first-class quality. Aerobic organisms are usually rapidly incapacitated by the exhaustion of oxygen, accompanied by the fall to an *r*H which they cannot tolerate, but the facultative coliforms are always a potential menace. Sluggishness in acid formation by streptococci may be a mere varietal property—the differences in rate from strain to strain may be very great—but there are other potent causes of failure of growth at the rate necessary to suppress contaminants and provide curd of the desired physical character.

Much has been written in recent years on the depredations of bacteriophages in cheesemaking. The origin of bacteriophages is still unknown, but those attacking the streptococci of starters behave exactly as those of other organisms and in a growing actively dividing culture simply cause their disintegration. The " burst rate " or the average number of particles of phage liberated on the disintegration of a single streptococcus varies, but may be as high as 60. Each particle, more or less specific for a single strain of streptococcus, is capable of attacking a fresh cell, and it is obvious that the rate of destruction will soon outstrip the rate of growth. Acid development ceases, it is impossible to rennet under anything like suitable conditions, and even if coagulation occurs the curd is of a quite unsuitable physical type. It is, in fact, an intractable mass from the cheesemaker's point of view. If it is impossible to await the resumption of acid formation by strains from the starter or from the milk itself which are resistant to phage, starter failure from this cause is bound to result in bad cheese. The necessary expulsion of moisture by curd contraction is impossible. Instead of a homogeneous green cheese with a high acidity, there will be a mass of unbound fragments of comparatively low acidity, providing suitable conditions for the growth of a variety of organisms which would otherwise be held in check.

Similar results may flow from the growth, in the raw milk, of common streptococci of a type producing inhibitory substances. These organisms themselves produce acid, but usually at a rate insufficient to replace starter, and they inhibit almost completely the growth of added starter if conditions of storage and transit have been favourable for their active growth. Attempts to make cheese from bulks containing significant quantities of such milk are bound to result in failure and pasteurisation is no remedy as the inhibitory substances are heat-stable.

Up to the stage of arrival on the shelf of the ripening room, therefore, the immunity from undesirable fermentations is almost entirely due to the overwhelming activity of the lactic streptococci, which produce conditions in which contaminants are unable to grow. It must be emphasised that few of them are destroyed ; they are only effectively suppressed.

What are the conditions in the green cheese itself ? The water content of the curd has been reduced by contraction during the cooking process, by salting and by subsequent pressure in the cheese press. Most of the lactose of the milk has been removed with the whey when it is drawn off, and by the earlier fermentation, but some still remains in the cheese. This is rapidly removed by the continuing lactic fermentation in the cheese which retains heat by reason of its mass. Within about 2 days, however, all fermentable free carbohydrate has disappeared. The moisture content is now some 38 per cent. and the *p*H about 4·9 to 5·0 as compared with 6·6 to 6·8 for the fresh milk.

The presence of the salt which is added, is in itself important. It may be assumed that much of it is in solution in the aqueous phase and, if as is usual, salt is added to the curd before moulding at the rate of about 2 per cent. by weight, the salt concentration will be about 4 to 5 per cent. In spite of this apparent handicap the residual lactose is removed within about 2 days by the lactic streptococci. The moisture content is still sufficient to support vigorous growth of any organisms which can tolerate the conditions of comparatively low *p*H and declining temperature, together with the concentration of salt. The biological stability of cheese of this type rests mainly on the fact that few bacterial types which may cause spoilage are so endowed. The moulds, the spores of which gain access from the air, are, of course, always present and are inhibited simply by the anaerobic conditions in the tight mass of curd. The yeasts are mainly inhibited by the lack of fermentable carbohydrates.

But the role of the lactic acid bacteria is not yet complete. The lactobacilli, present in small numbers even in the milk, but hitherto inactive, assume growth, deriving their energy, it is believed, from the calcium lactate now present in the curd. They grow well even in the presence of the considerable salt concentration and add to the acidity. With the exhaustion of the lactose there is, of course, a steady decline in the living population of streptococci. Nevertheless, they can be recovered in some numbers from old cheese and it has been established that *Str. faecalis*, a very hardy species, may also in some cases survive for long periods.

It will be appreciated that these are all acid-forming organisms and, in the main, add to biological stability simply because the aerobic and proteolytic types are unable to thrive or even grow under the acid conditions obtaining. As ripening proceeds, however, the breakdown of the proteins, mainly casein, by the enzymes of the rennet and to a lesser extent of the milk itself, results in a steady rise in *p*H. The process at normal storage temperature is slow. Eventually, however, the *p*H may have risen to a point where the proteolytic anaerobes can grow. Within a short time of the beginning of ripening the actual conditions of anaerobiosis are quite suitable. If the spores or vegetative forms of organisms such as *Clostridium putrificum* are present in sufficient numbers, they may cause serious trouble when the *p*H has risen in the course of ripening to about *p*H 6·2. Some strains are even capable of beginning growth at *p*H values below this figure. The effect of their growth is disastrous since they produce H_2S and mercaptans, evil-smelling derivatives of protein breakdown. " Dead Man's finger " is, indeed, an apt trade description of the condition. In well-made cheese the fault is fortunately rare, but it is easy to appreciate what may happen when there is a failure or partial failure of acid formation.

The coat of a properly made cheese should, because of evaporation, be low in moisture and resistant to the growth of micro-organisms. If, however, cracks appear they may extend to the interior of the cheese, and admit air. Some aerobic types may then start to grow. Thus moulds of some species and strains will grow in an atmosphere containing as little as 4 per cent. oxygen. The prized Blue Cheddar is, however, simply a bad specimen of its kind. When the humidity of the storage room is excessive, mould and even bacterial growth may take place at the surface of the cheese and initiate a process of deterioration.

It is impossible in the space to give more than a general picture of a complex system under normal conditions. There are, of course, various devices known to the good cheesemaker for combating difficulties during manufacture, but unless he eventually succeeds in getting the necessary acidity, his cheese will be poor. The stability of cheese, like that of so many products, rests essentially on the lactic acid fermentation, which, assisted by rennet, is skilfully governed to bring about modification of the protein to produce a compact and anaerobic mass. Anaerobiosis *and* acidity form a system which is very stable biologically.

It is doubtful whether the soft and semi-hard cheese can be considered to possess biological stability in the defined sense.

Butter. The fat content (about 82 per cent.) of butter is high and the nitrogen and water content (nearly 16 per cent.) low when compared with those of cheese, but micro-organisms of many kinds may, nevertheless, grow profusely in it.

Butter may be considered as an emulsion of water in fat and when it is well made the water droplets are small in size and evenly distributed throughout the mass. It is necessary to realise that the water phase is not continuous and that residues of casein and other bacterial nutrients are also present.

That the water phase is not continuous is an important fact in determining the types of micro-organisms causing spoilage of various types in butter. In the traditional process buttermilk should be removed during washing and the water droplets ought, therefore, to contain little in the way of nutrients for bacteria. If bacteria should be present any growth will be restricted to a series of single droplets, *i.e.* there will be a series of isolated foci and there will be no continuous growth throughout the mass. Fat itself is well known to be biologically highly stable. (Its chemical stability is altogether a different matter.) For this reason spoilage, by bacteria, of the interior of the mass of well-made butter in which the water is well distributed in small globules, should not be a very serious matter and if the butter is salted at the rate of 1½ to 2 per cent. the salt concentration will be high enough to discourage any but halophiles. When it is considered that the conditions within the butter probably quickly become anaerobic, owing to the rapid absorption of the small volume of oxygen by the unsaturated fatty acid glycerides (thus initiating very early in its life that oxidation, which especially in the presence of a catalyst, is so dangerous), it will be appreciated that, in general, bacterial spoilage of the mass should rarely take place.

If, however, the water used for washing is impure and washing is not thorough and if the distribution is bad, resulting in the presence of large water pockets, bacterial growth may be rapid. That the majority of the organisms in butter are probably not in the fat phase was shown by some observations made some years ago. In making plate counts of butter, especially in the lower dilutions, some difficulty may be caused by the presence in the plates of fat globules which may resemble colonies of bacteria. If the sample is liquefied at about 50° C. in a small sterile separating funnel and kept warm, the water and curd quickly settle to the bottom and as a rule over 95 per cent. of the total organisms present are found in the water. This method of examination has obviously something to recommend it.

Cream for buttermaking may be safely heated to temperatures much higher than those which are suitable for milk and this is an additional reason why there is little excuse for high bacterial populations in the body of butter. It is widely accepted that it is necessary to heat cream and other materials containing a high proportion of fat to temperatures rather higher than, say, milk with about 4 per cent. of fat, in order to achieve the same degree of destruction of organisms of the same numbers and types. If some of the bacteria are indeed in the fat phase, it may be that they are dehydrated to an extent sufficient to permit their survival for a longer time. So much for the bacteria ; but the position is different with moulds and yeasts, which are always a menace to butter. The former, by virtue of their larger size, are not confined to single globules and may and do extend their hyphae throughout the mass, especially near the surface ; their lipolytic enzymes may, of course, diffuse very widely. In both unsalted and in highly salted butters moulds may be very troublesome. They secrete lipases which quickly ruin flavour and many of them like *Penicillium, Aspergillus,* and *Oidium* are coloured.

It is, therefore, very important to ensure that the special type of paper in which butter is wrapped for sale shall be free from mould spores, because at the surface the conditions for their growth are very favourable, *e.g.* moisture which would otherwise evaporate is retained beneath the paper. Large consignments of many tons of wrapped butter were ruined from this cause during the late war.

Before leaving the discussion of the conditions and events in the mass of butter, some mention should be made of the butter produced by the continuous or direct buttermaking machines. These have been in the process of evolution for some years and during the war notable advances in design and performance were made in Australia, Switzerland, Germany, and Sweden. It is a feature of butter made with these machines that the fat is remarkably stable. Thus it was found that although at the *surface* of a slab of butter not more than 2½ in. thick oxidation and rancidity were marked, it retained its flavour, substantially unimpaired, within the mass. It is a feature of such butter that the water globules are minute, indeed microscopic, and very homogeneously distributed and the salt is equally well disseminated. In globules of such minute dimensions bacterial growth may well be discouraged because of the large surface forces involved, if not for simple reasons of space.

The possibilities of, and the limitations to, the growth of micro-organisms within well-made butter have been discussed, and it remains to consider events at or near the surface. Those organisms which cause discolorations and rancidity are the most important. The strongly aerobic *Pseudomonas fluorescens* and other members of the genus and various coliform types are strongly lipolytic. They are common in water and for this, if for no other reason, it is essential that water used for " washing " in a butter factory shall be exceptionally pure.

Mere public health standards of bacteriological quality are likely to be insufficient. Some of these organisms are capable of growing at fairly low temperatures and some members of the genus *Achromobacterium* may proliferate at − 3° C. if free water is still present. Although salt in butter obviously exerts a sparing action on the growth of micro-organisms (if the percentage is high, as in the old-fashioned Irish salt butter, it may be very effective) it is not an absolute barrier. Thus Hiscox found that *Pseudomonas nigrifaciens* forms a purplish-black pigment and has its maximum effect in salt butter at fairly low temperatures.

It is for many reasons possible to attain a better standard of hygiene in the manufacture of butter on a large scale than in cheesemaking. In large scale buttermaking the cream is pasteurised for public health reasons and to avert the formation of acid, which catalyses fat deterioration. In subsequent operations the chances of contamination are less than in cheesemaking. Nevertheless butter has not, on the whole, that solid biological stability conferred upon hard cheese by its acidity and its anaerobiosis. Because of the chemical vulnerability of its fat butter can only be safely kept for long periods by storage at very low temperatures, *e.g.* − 15° F.

Of the two products which have been discussed, cheese is by far the more interesting ; it is, in fact, in spite of adverse appearances, highly biologically stable.

Sweetened Condensed Milk. For this product absolute sterility is not essential, but a low bacterial content is advisable. Before concentration the milk is preheated, *i.e.* subjected to what is in effect a pasteurisation process during which natural enzymes of the milk and a proportion of the organisms are destroyed, the percentage destruction and the types of bacteria surviving the process being determined by the original flora of the milk and the cleanliness of the plant. As the milk is not again heated at a temperature sufficiently high to destroy heat resistant organisms, the time/temperature conditions of the preheating process and the original quality of the milk are important factors in determining the biological stability of the finished product.

The concentration of the solids in the finished product provides a medium which is not favourable to the growth of micro-organisms, but the most potent inhibiting factor is the addition of cane sugar in concentrations of about 40 to 45 per cent. While such sugar solutions have little lethal effect on micro-organisms, the high osmotic pressure causes plasmolysis of most living cells and is thus effective in arresting growth. Yet another factor, the lack of available oxygen, serves as a check on organic growth. Very little oxygen remains in solution in the concentrated milk product and if aeration is avoided during cooling or air withdrawn from the milk before filling it into cans, the available oxygen is confined almost entirely to the air space in the tins. This should be reduced to a minimum. These conditions in the tin make for microbiological stability, but they may be rendered ineffective by the presence of certain types of organisms.

Organisms can sometimes be recovered in large numbers even from apparently sound tins of sweetened condensed milk, but for the most part they are inert in it and of no major importance from the point of view of stability. Some strains of yeasts are, however, able to develop under the conditions obtaining even in properly prepared tins. Strains of *Saccharomyces* are known to grow in high concentrations of sugar and have been shown capable of growth in sweetened condensed milk, but they are rarely isolated from commercial samples, and if they do not ferment lactose or saccharose they are not obvious disturbers of stability. Two types of yeast, *Torula lactis-condensi* (oval cells) and *T. globosa* (round cells) are, however, dangerous. They are both of widespread occurrence, and induce alcoholic fermentation in saccharose, with consequent " blowing " of the tins. *T. lactis-condensi* is the more active of the two and in cases of heavy infection the tins may burst within a few days. *T. globosa* is not so violent in its action and, in the absence of *T. lactis-condensi*, rarely causes more than a distension of the tin. The natural habitat of these organisms has not been established, but they may sometimes be isolated from cane sugar which is therefore suspected of being the source of infection at the factory. Neither of these organisms shows a high resistance to heat and they would normally be destroyed during the manufacturing process. When an outbreak of this trouble persists the most prolific and immediate source is no doubt the plant, premises, and equipment which have become contaminated either directly from the sugar or from fermented milk. These torulae may occasionally be isolated from sound tins which show no trace of alcoholic fermentation. In such cases it is unlikely that growth has been inhibited by a concentration of sugar higher than usual, as they will grow in saturated solutions of cane sugar. The strain in question may, however, be less resistant than some to high sugar concentrations, or the initial infection may have been so slight that the available oxygen in the tin did not allow an increase in numbers sufficient to initiate alcoholic fermentation.

Certain moulds, too, are able to grow in high sugar concentrations, and in tins of sweetened condensed milk may give rise to " buttons ". The mould develops normally at first, but its growth is checked as the oxygen in the air space above it is exhausted. The mould may die and disintegrate but the enzymes in the hyphae remain active and coagulation of the casein continues. The " button " may thus increase in size although organic growth has ceased. Only a few moulds (*Aspergillus repens*, *Aspergillus glaucus*, *Catenularia fuliginea*, *Penicillium terrestre*, and a species of *Actinomyces*) have so far been directly implicated, but it is probable that others may be equally capable of producing " buttons ".

Bacteria are less obviously concerned in the deterioration of condensed milk. The numbers and types that may be found in it vary according to the quality of the raw milk and the care with which the product has been handled. The bulk of the bacterial population consists of cocci. These grow slowly, if at all, under conditions obtaining in a well-produced tin of condensed milk. Some of them may, however, produce acidity, others a rennin-like enzyme, and still others a gummy product from the saccharose, all of which may be in some degree concerned with the thickening of condensed milk, which, nevertheless, is mainly a chemical problem. Gas-producing bacteria, such as the coliform organisms, and saccharose-fermenting anaerobes, may be present in the tins, but will not usually be capable of growth unless the controlling factors have been relaxed.

Unsweetened Condensed (Evaporated) Milk. No inhibitory substance is added to this product, which must therefore attain absolute sterility to ensure microbiological stability. To this end a severe heat-treatment is used. An aerobic conditions within the tins are an added safeguard. Careful control of the quality of the raw milk and the conditions under which it is produced is advisable.

After the normal preliminary processing the concentrated milk is packed into tins, sealed and heated at 240° to 245° F. for 15 or 20 min. With comparatively few exceptions this provides a stable product. Defects arise from insufficient or unevenly distributed heating, faulty sealing of the tins whereby the anaerobic conditions are weakened, and the presence of highly resistant bacterial spores, some of which are able to survive heating at 245° F. for 15 min. This severe treatment is apt to cause undesirable physical and chemical changes in the milk, and to avoid these a milder treatment is sometimes adopted, with a resultant greater danger of the survival of spores.

If the tins are well prepared, only anaerobic, or micro-aerophilic bacteria should be able to develop. The most common faults of evaporated milk are due to organisms of this type. Gassiness, often accompanied by putrefaction and foul odours, is due to anaerobic spore-bearing bacteria belonging to the butyric acid group. They produce large quantities of gas, a mixture of hydrogen and carbon dioxide, even in the absence of free fermentable sugars. The organisms most frequently implicated in this fault are *Clostridium putrificum*, *Cl. sporogenes*, and *Plectridium foetidum*. Other faults, such as sweet-curdling and bitterness, have been traced to aerobic spore-bearers which were present in sufficiently large numbers to initiate enzyme action or, more probably, which found sufficient oxygen in the cans to support growth. Spoilage due to the action of non-heat resistant bacteria may sometimes be encountered, but unless the heating process has been grossly inadequate, their presence can only be due to seepage into the tins through faulty sealing.

Sterilised Milk. Sterilised milk, like evaporated, depends for its stability on heat-treatment at high temperatures, and on anaerobic conditions within the bottle, but its water content is not reduced. The cases are not exactly parallel because sterilised milk is intended primarily to provide a supply of liquid milk for domestic purposes, and is not expected to keep sweet for excessively long periods. The milk, filled into narrow-necked bottles closed by swing stoppers with rubber washers or crown corks, is heated at 100° C. (212° F.) in current steam, or at 105° C. (220° F.) or even higher temperatures with steam under pressure. With the continuous sterilising plant crown corks, which are self-sealing, are essential. During the processing, vegetative forms of bacteria are destroyed and only resistant spores survive. The chief faults in sterilised milk are, therefore, due to spore-bearing organisms; those due to non-sporing bacteria can only result from wrong processing or after-contamination of the milk through ineffective seals. There should be only restricted growth of aerobic bacilli if the " vacuum " in the bottles is good. Nevertheless, faults due to their activities often occur, indicating the difficulty of obtaining perfect seals. Serious losses may result from defects and the heat-treatment is often increased in the hope of avoiding spoilage by destroying all spores. Wide variations in heat-treatment from dairy to dairy, such as from 210° F. for 15 min. to 228° F. for 40 min. have been reported.

Recently Hirschman, and Simonart and Debeer have suggested that the spore content of milk could be considerably reduced by means of the ultra-centrifuge. Because of their higher density spores are thrown out more rapidly than the vegetative forms of bacteria.

One of the most common faults is sweet curdling which has been traced to the action of rennin-like enzymes of atypical forms of *Bacillus cereus* and *B. subtilis*. Gassy fermentations may also occur.

Another fault which has often assumed epidemic proportion is the development of " Carbolic taint ". No visible change occurs but a characteristic smell and taste develop due to the production of cresols in the milk. The causal organism produces highly resistant spores, which will readily survive the less drastic heat treatments. With changing methods at farm and factory this taint does not now, apparently, assume epidemic proportions as was frequently the case in the 1930's. The causal organism (*B. circulans*) is still, however, cited as one of the major contaminants of sterilised milk.

If transfers of sporing cultures are made in milk in the normal way the spores apparently do not germinate and are lost by dilution, and by the third and fourth generation a non-sporing, non-resistant culture is obtained which cannot be induced to sporulate by any of the known methods. In this way it differs from a non-sporing milk culture of ordinary aerobic bacilli, which readily produce spores when transferred to suitable media. If, however, the cultures are heated at boiling-point at the time that the transfer is made from the sporing culture to the milk, the spores germinate and form a new generation of spores. Thus bottles of milk in which the carbolic taint has developed will therefore be full of spores and the very treatment that is expected to, and generally does, give microbiological stability to the product provides ideal conditions for the propagation and continued survival of this organism which destroys its stability.

Faults due to the activity of thermophilic organisms have seldom been recorded. Morgan has, however, connected the development of bitter flavour in sterilised milk with the presence of *B. thermoacidurans*, a thermophile which would also grow at ordinary temperatures, and Clegg traced an outbreak of clotting of milk with " graining " of bottles to the action of thermophiles. Until recently the sterilisation process usually included water-cooling of the bottles immediately after the heat-treatment. Thus the milk was at a temperature suitable for the growth of thermophiles for a negligible period and little attention was paid to them. With changing methods there are, however, signs that they may assume greater importance. There is a tendency to " sterilise " the bottles of milk in large batches, arrange the hot bottles in large stacks and leave them to cool in the air. Cooling is slow, especially in the centre of these stacks, and the milk may be at suitable temperatures for a period sufficiently long to allow the germination and further development of any residual spores of thermophiles that may be present in the milk. Intensive researches by Burton *et al.* did not reveal an increase in the thermophilic count during this slow cooling. The rapid development of thermophiles and the fact that, for many strains the period of logarithmic growth is within 6-8 hours after inoculation, should not, however, be disregarded.

Refs.: Hiscox and Christian (1931), *JDR*, **3**, 106, 113; Morgan (1943), *SAB*, 131; McKenzie (1945), *DI*, **10**, 334; Clegg (1950), *JSDT*, **3**, 238; Burton *et al.* (1953), *JSDT*, **6**, 98; Rowlands (1953), *JSDT*, **6**, 173; Tierie (1953), *NMDJ*, **7**, 138; Simonart and Debeer (1953), *NMDJ*, **7**, 117; Hirschman (1951-52), *Arb. Ber. Südd. Vers. Forsch. Milch.*, Weihenstephan, **2**, 1-2, 41.

Milk Powder. The production of dried milk powder involves a preheating (pasteurising), a condensing and a drying process, which, though differing from plant to plant, are similar in essential details. The time/temperature combination adopted for preheating is important, for on this and the bacteriological quality of the raw milk depend the numbers and types of bacteria remaining in the finished powder, assuming that there is no after-contamination from the plant. A slight further reduction in numbers occurs during the actual drying, generally greater in the roller than in the spray-drying process. Recontamination from the air may occur during the subsequent cooling and packing.

The flora of dried milk powder should be predominantly thermoduric, the proportion of non-resistant organisms depending on the efficiency with which the plant has been cleaned and sterilised, the care with which the process is operated, and the degree of protection from air contamination given to the powder. With attention to detail it is easily possible to limit the plate count to a very few thousand organisms per 1 g. of powder.

The organisms most frequently reported are heat-resistant strains of streptococci (*Str. durans*, *Str. faecalis*, *Str. bovis*, and *Str. thermophilus*) micrococci, microbacteria (corynebacteria), and aerobic and anaerobic spore-bearing bacteria. Coliform organisms are frequently found ; a few strains may be heat resistant but in general they should not survive the preheating process and their presence indicates contamination from the plant. The presence of yeasts and moulds is generally due to contamination from the plant and the air.

Some workers have noted that the plate count of dried milk powder progressively decreases as the powder ages and have concluded from this that the bacteria tend to die during storage of the powder. This is no doubt true to some extent, but the technique of reconstitution of the powder in preparation for plating may also have been a factor contributing to this change in plate count. In some laboratories it has been the custom to reconstitute the powder in water or other liquid held at room temperature. Recent work has shown, however, that if the reconstituting medium is held at 50° C. a higher plate count results. It appears that this increase is not primarily due to the breakdown of clumps of micro-organisms, but is a response to the heat stimulus thus applied to the dry bacteria, many of which remain dormant unless stimulated in this way. The same effect has been observed for spray-dried cultures of lactobacilli and it was also noted that the effect increased with the age of the dry culture. No similar increase in plate count is found when milk powder is reconstituted in the cold and then warmed to 50° C.

Although there is no good reason why dried milk powder should contain more than a few thousand bacteria per 1 g. of powder, plate counts vary and in some cases are unnecessarily high. Even so, if the moisture content of the powder is normal ($<$ 4 per cent.) the bacteria will remain dormant and unable to cause changes in the powder. Dried milk powder is one of the most stable of the milk products, as long as it remains in the dry state. When it is reconstituted and used in the preparation of other milk products, especially if there is an opportunity for an incubation period, the bacteria may multiply and cause undesirable changes. In this connection the enterococci and staphylococci would be especially obnoxious, with the added possibility of causing food poisoning.

In spite of the general inactivity of the bacterial population, dried milk powder tends to deteriorate with age, especially when stored under warm and humid conditions. With faulty packing, the powder may absorb water and as soon as the moisture content reaches a suitable level, there may be bacterial growth with attendant changes in the powder. But even in the dry powder enzyme action may proceed. One of the most dangerous of these is lipase, of which some is natural to milk and some passes in from lipase-secreting organisms. This enzyme is more resistant to heat than many others and may survive in milk which has been preheated at too low a temperature. The rancidity produced by this enzyme may be avoided by using a suitable preheating temperature and it is also an advantage to dry the milk in the freshest state possible, before significant bacterial development has begun. Tallowiness, another chemical defect, due to oxidation of the fat, and therefore serious only in whole milk powders, may be controlled by using a preheating temperature sufficiently high to produce sulphydryls in the milk, which by their reducing action counteract the oxidation. Packing the powder in an inert gas and the addition of antioxidants to the powder are also effective remedies. *See* Butter; Cheese, p. 168; Condensed and evaporated milk; Flavours; Milk powder; Sterilised milk.

Refs.: Baumgartner; Cronshaw; Hammer; Hunziker; Hunziker (B); Jacobs; McCulloch; Prescott and Dunn; Rogers; Tanner.

STAINLESS STEEL. Stainless steels are essentially alloys of iron, chromium, and a little carbon, some containing nickel. All of these have high resistance to corrosion or scaling and heat, chromium conferring resistance to corrosion and the nickel alloys having the highest tensile and creep strengths, *e.g.* the 18 per cent. Cr and 8 per cent. Ni alloy.

Stainless steels are steadily displacing tinned bronze, tinned mild steel, and other materials in the dairy industry in all places where strength and resistance to corrosion are important. In some circumstances, however, aluminium and nickel alloys have certain advantages. *See* Metals.

Refs.: Davies; Farrall; Speight (1947), *JSDT*, **1**, 13.

STAINS. *See Classification in dairy bacteriology; Microscopic count.*

Refs.: Eyre; Gurr (1953), A Practical Manual of Medical and Biological Staining Techniques, London.

STANDARDS (CHEMICAL) AND ANALYTICAL METHODS FOR MILK. There is no legal definition of milk and the word " quality " in respect to milk is used very loosely and sometimes includes both chemical composition and bacteriological quality. These two properties are quite independent and unrelated one to the other.

The fact that milk contains fairly large proportions of fat, protein, sugar, and salts has been known for a long time but it was not until reasonably accurate analytical methods, suitable for routine use, were devised, that we obtained any general knowledge of the way in which the chemical composition of milk varied. From a general point of view the chemical constituents of milk are conveniently divided into two parts, fat, and the solids-not-fat, the fat including also the lipoids such as lecithin and the fat-soluble vitamins A and D, and the solids-not-fat fraction containing everything else, casein, albumin, globulin, lactose, mineral salts, and the water-soluble vitamins B_1, B_2, and C.

For some time previous to about 1900 the commonly used analytical methods for milk consisted of a total solids determination by driving off the water, and the measurement of specific gravity by a special hydrometer (usually referred to as a lactometer). The usefulness of the latter is derived from the fact that whereas the fatty portion of milk has a specific gravity of about 0·9 the solids-not-fat have a specific gravity considerably in excess of 1·0. The specific gravity of milk is therefore lowered by increasing fat content and raised by increasing solids-not-fat. By the use of suitable formulae it is possible, knowing the total solids (*i.e.* fat plus solids-not-fat), to estimate the fat and solids-not-fat separately from a knowledge of the specific gravity of the milk. However, the gravimetric determination of total solids is not a suitable procedure for the routine examination of large numbers of samples and is also costly as it requires a good balance.

Various attempts were made to devise a simple routine method for the direct estimation of fat and in the last decade of the nineteenth century the Babcock and Gerber methods were brought out for this purpose. They consist essentially in treating the milk with strong acids which disrupt the protein membrane round the fat globule and so allow the fat to form a continuous phase at the surface of the liquid, separation being accelerated and completed by centrifuging. The Babcock method is in almost universal use in America and the Gerber test is practically universal in this country.

The development of these direct fat-estimating methods removed the necessity for the gravimetric method and virtually the whole of the milk supply of this country is now controlled by the Gerber method and the solids-not-fat tests by the lactometer method. The milk of some 157,000 dairy farmers in this country is tested usually once or twice a month by these tests and in addition bulk supplies are likewise tested.

The evolution of these simple analytical methods also resulted in giving the authorities fairly precise information about the composition of different sorts of milks at different times of the year and how the composition of milk could be affected by various factors. This led to the ultimate adoption of chemical standards for milk. These were based upon the consideration of a large number of analyses made in all parts of the country at different times and the presumptive standards adopted were, for fat, 3 per cent. and for solids-not-fat 8·5 per cent.

The fat is by far the more variable factor, being easily influenced by such factors as breed, yield, the time of the year, type of feeding-stuffs, stage of lactation, etc. The solids-not-fat content is much more constant and although influenced to some extent by the same factors that control fat, varies between much narrower limits. For this reason it was possible to make a chemical standard for the solids-not-fat content much closer to the average value than in the case of the fat content. The latter varies from about 3·4 per cent. in May, when the yield of milk is at its highest and the fat content at its lowest, up to about 3·9 per cent. or even higher in December. The standard of 3·0 per cent. was adopted on the argument that no milk produced from an ordinary herd in this country would under normal conditions ever fall below 3 per cent. in fat content. Similarly, the value for solids-not-fat content normally varies from about 8·6 to 8·9 per cent.

At this time there was little control of the quality of milk and the sale of milk was in the hands of a large number of small vendors, some of whom were not too scrupulous, and the proportion of adulterated milk was undoubtedly high. There was available no specific test to detect the addition of water to milk, and the authorities therefore had to adopt the basis that if milk fell below the presumptive standards of 3 per cent. fat or 8·5 per cent. solids-not-fat it should be presumed to be watered unless the contrary was shown. This worked very well in practice because the milk seller could always fall back on the " appeal-to-the-cow test ". This meant that, if accused of watering his milk because of its low chemical composition, he could " appeal to the cow " or have samples taken from the milk as produced from his herd. If the tests on milk as taken agreed with those of his milk as sold to the public then it was obvious that his milk was genuinely deficient in fat or solids-not-fat, and had not been adulterated.

In the course of time it became recognised that the solids-not-fat could have a low value for a pathological cause not previously suspected, mastitis. This disease is an inflammation of the udder caused by certain streptococci and other organisms which frequently results in the secretion of milk low in solids-not-fat. Such milk, usually called " abnormal milk " or " mastitis milk " frequently has a solids-not-fat content of less than 8·5 per cent., and until scientific knowledge extended and a more accurate test for water became available such milk was frequently suspected. *See* Abnormal Milk and Mastitis.

The solution to this problem came when the development of the freezing-point test gave public analysts a more certain method for the detection of added water in milk. This test depends upon the fact that genuine milk has a freezing-point which usually lies between — 0·540° and — 0·550° C. A small proportion of samples from individual cows have a freezing-point which may be as low as — 0·530° and as high as — 0·560° C.

Following upon this discovery there has been a general agreement amongst dairy chemists and public analysts that if milk has a freezing-point *depression* which is less than 0·530° C. then it can certainly be assumed that the milk contains added water. The adoption of this as the standard gives a tolerance equivalent to about 3 per cent. water as the average freezing-point depression is about 0·544° C. It is, therefore, customary nowadays for milks to be tested first by the fat and solids-not-fat test and then, if either is suspiciously low, for a freezing-point test to be made. The freezing-point test is not yet a statutory test but it is now frequently accepted in a court of law as supporting evidence for or against the allegation that the watering of milk has taken place (p. 485).

General Chemical Composition of Milk. The effect of various factors on the fat and solids-not-fat content of milk is illustrated in the following Tables :

See Tables Be I (p. 119) and Br I (pp. 122-123).

Different sets of figures give slightly different results for breed values but all show quite clearly that Jersey and Guernsey milks are the richest and Friesian the poorest. There has been a slight fall in the average solids-not-fat content of the country's milk over the past 20 or 30 years. Although the exact reasons are not known it is probable that the increase in the number of Friesian cattle has been a major factor.

TABLE St I

FACTORS AFFECTING FAT CONTENT

Favourable	*Adverse*
Good management	Feeding cod liver oil
Short milking interval	Long milking interval
Complete milking out	Incomplete milking out
Young cows	Old cows
Later stage of lactation	Flush of milk (2nd to 5th months)
Cold weather	Warm weather
Moderate exercise	Rest
	Abnormal conditions, excitement, etc.
	Inexpert milkers

Other factors are the individuality of the cow and breed.

TABLE St II

FACTORS AFFECTING SOLIDS-NOT-FAT CONTENT

Favourable	*Adverse*
Young cows	Mastitis (disease of udder)
Later stage of lactation	Old cows
Spring pasture	Flush of milk (2nd to 5th month)
	Indoor feeding

Broadly speaking, the fat content of milk is more variable than the solids-not-fat content which is fairly constant.

TABLE St III

SUMMARY OF ACCURATE (REFERENCE) AND SIMPLE ROUTINE TESTS FOR MILK

Constituent	*Accurate tests*	*Routine tests*
Fat	Röse-Gottlieb Adams (ether extraction)	Gerber Babcock (acid-centrifugal separation)
Solids-not-fat	Gravimetric (evaporation of moisture and correction for fat)	Lactometer (specific gravity and correction for fat)
Added water	Freezing-point	Lactometer and conductivity measurements
Lactose	Polarimetric	Polarimetric
Protein (total)	Total nitrogen (Kjeldahl)	Sörensen titration (with formalin)
Casein	Precipitation at *p*H 4·6 and weighing	Precipitation at *p*H 4·6, redissolving and Sörensen titration
Salt (NaCl)	Silver titration after digestion with HNO_3	Conductivity
Ash	Heating to 450° C.	
Visible dirt	Official S.P.A. method (centrifugal)	Filter pad or "sediment tester"

See Composition, factors affecting; Fat; Legal aspects; Quality payment; Routine tests; Solids-not-fat; Total solids.

Refs.: British Standards Institution Specs. Nos. 696 (Gerber test) and 734 (solids-not-fat test); Soc. Publ. Anal., Milk Products Sub-Committee (1927), *A*, **52**, 402; (1932), **57**, 630; (1945), **70**, 106; Richmond; Davis (1952), *A*, **77**, 499.

STANDARDS FOR DAIRY PRODUCTS. *See* British Standards Institution; Butter; Cheese; Condensed and evaporated milk; Ice cream; Legal aspects; Milk powder; National Milk Testing Scheme; Pasteurisation; Phosphatase test; Quality payment; Routine tests; Soft cheese; Sterilised milk; Testing of milk supplies.

Refs.: Bell; Harvey and Hill; Richmond; Swift; Min. Health (1937), Memo 139/Foods, H.M.S.O.; S.R. and O (1946), No. 10, H.M.S.O.; Davis (1952), *D*, **69**, 347, 407 (bacteriological).

STANDARDISATION OF FAT CONTENT OF CREAM (OR MILK). How many lb. of cream of A per cent. fat must be mixed with that of B per cent. fat to make a mixture containing C per cent. fat ?

A(45) **C-B(7)**

C
25

B(18) **A-C(20)**

Construct the above rectangle with the required figure for fat (C) in the centre. Subtract on the diagonals to give C-B and A-C. The mixture then is C-B lb. of A per cent. cream and A-C lb. of B per cent. cream.

For example, if the figures represent fat percentages, 7 lb. of 45 per cent. fat must be mixed with 20 lb. of 18 per cent. fat to give 25 lb. of 25 per cent. fat.

This method can be used for standardising the fat content of a product from whole milk; skim and whole milk; cream and whole or skim milk, and milk and butter for reconstituted cream. *See* Butter; Cream; Milk powder.

STANDARDISATION OF MILK. The adjustment of the fat content of consumer milk (*e.g.* to 2·5, 3 or 3·5 per cent.) or of manufacturing milk to obtain a given fat value in the final product.

Arguments in Favour of Standardisation of Milk to, e.g., 3·0 per cent. Fat.

(1) The purchasing public could always rely on getting a milk of practically constant composition and nutritive value.

(2) A large quantity of milk fat would become available, which could be sold as cream or turned into butter. This would mean that cream would be available all the year round and the amount of butter produced would also increase.

(3) Standardisation of milk by distributing dairies would provide a powerful argument for the purchase of milk from the farmer on chemical quality basis, either fat or total solids and from this point of view might be considered a desirable feature.

(4) It is well recognised that not all adults and children like milk. Some find difficulty in digesting it and a few are definitely allergic to it. It might reasonably be asserted that the sale of milk standardised at 3 per cent. fat instead of at a fat content varying from about 3·3 per cent. to above 4 per cent. fat, might result in a reduction in the number of people who find difficulty in digesting milk. In other words, a small minority of people who have hitherto taken very little or no milk because of digestive troubles, might find it possible to consume milk at a standardised lower fat content.

If milk were standardised to, say, 3 per cent. all the year round, then per gal. of milk most cream would become available about December, and least in May, but the fact that the production in May would be much higher than in Autumn and Winter would partly compensate for this. Doubtless, the greatest demand for cream would be in June and July in the soft fruit season, but the available cream could be allocated for retail cream sale or manufactured into butter, according to the demand for cream.

A simple calculation will indicate the amount of cream or butter that would become available. Thus, if we assume that the average fat content of milk in England and Wales is 3·6 per cent. and that the annual milk production is 1,500,000,000 gal., then the amount of milk fat which would become available would be 1,500,000,000 × 10 × 0·6 per cent. = 90,000,000 lb. Considered in terms of coffee cream at 18 per cent. fat, this is equivalent to 50,000,000 gal., and considered as cream of 48 per cent. fat content, would be equivalent to 18,700,000 gal. If all this fat were converted into butter containing 82 per cent. fat, then the total extra production of butter would be 110,000,000 lb., or about 1,000,000 cwt.

At the present time (1952) the annual home production of butter in England and Wales is about 80,000 cwt., and the imported butter amounts to about 5,000,000 cwt. Calculated per person per year this extra available milk fat would give everyone about 10 pints of 18 per cent. cream, or about 3½ pints of 48 per cent., or nearly 3 lb. of butter annually.

Disadvantages of standardisation of milk to, e.g. 3 per cent. fat. (1) Probably the greatest objection that would be raised against universal standardisation would be the fact that all dairies would be required to be equipped with separators, in order that a small proportion of their milk might be separated so that the remaining bulk could be standardised to 3 per cent. fat by addition of skim milk. However, smaller dairies might be able to overcome the difficulty by buying skim milk from larger dairies. A further point is that the general trends of milk legislation are making it more and more likely that the smaller dairyman will no longer pasteurise his own milk, but will buy bottled pasteurised milk from a large dairy. This practice would automatically solve the problems as regards standardisation.

(2) The milk would generally look slightly " thinner " than it does at present. However, it is doubtful whether the ordinary public would notice any difference between 3·6 and 3·0 per cent. fat milks. Obviously there would be differences in the cream lines, but with the plentiful supply of cream the demand for cream line milk would probably fall off because people who usually want a good cream line milk do so in order that they may take the cream off and eat it separately with fruit, etc. A simple method of getting over the richness difficulty would be for the standardised milk to be homogenised, but this would raise the question of the extra cost involved in homogenisation. Nevertheless, as homogenised cream is nearly twice as " rich " in tea, coffee, etc., the public might welcome homogenised milk once they had learned to appreciate its qualities. *See* Condensed milk; Cream; Legal aspects; Milk powder; Quality payment.

Refs.: Cox (1954), *DSA*, **16**, 165; Carlberg (1949), *IDC*, **4**, 442.

STAPHYLOCOCCUS. A genus of spherical, Gram-positive, non-motile non-spore-forming bacteria forming grape-like clusters and often forming a yellow or orange pigment. The type species *S. aureus* is the organism of boils, pus, and abscesses and is common on skin and in milk. Some types are haemolytic and some can cause disease, *e.g.* staphylococcal mastitis (p. 662). *See* Classification ; Diseases; Food poisoning.

Refs.: Bergey; Wilson and Miles; Abd-El-Malek and Gibson (1948), *JDR*, **15**, 249 (staphylococci in milk); Shaw *et al.* (1951), *JGM*, **5**, 1010 (classification); Fairbrother and Southall (1950), *MBMH*, **9**, 170 (isolation); Davies (1951), *JGM*, **5**, 687 (coagulase); Ingram (1951), *JGM*, **5**, 30 (classification).

STARTERS. A starter may be defined as a culture of one or more lactic acid organisms, usually streptococci, in milk. In England the same starter is used for both cheese and butter and usually consists of *Str. lactis*, the common milk-souring diplococcus, and *Str. cremoris*, which differs in a few particulars from *Str. lactis*. In addition small numbers of aroma-producing streptococci, which grow very slowly in milk, may usually be isolated by enrichment methods.

STARTERS

The chief, and perhaps the only, function of a starter is the regular development of acidity in milk, cream, or curd. Starters may be scored on the basis of flavour, but there seems no real evidence that the type of starter is itself the source of the ultimate flavour of hard-pressed cheese, apart from the ordinary " lactic-acid flavour ". It is, however, important that the starter should not produce any off-flavours. Occasionally pure cultures may produce what are known as " malt ", " caramel ", and " burnt " flavours. The reason for this is not known, but it is probably due to a disturbed metabolism or fermentation process as a consequence of unsuitable environment. The usual reason for the production of off-flavours is contamination. Smell is perhaps the most delicate bacteriological test at our disposal. At the first suspicion of any off-flavour in a starter, it should be discarded.

Requirements of a Starter. The requirements of a starter are: (i) It should contain only the lactic-acid bacteria of the required type, usually *Str. lactis* and *Str. cremoris*, with some *Str. paracitrovorus* or other aroma-producing types. (ii) It must be free from any types capable of causing off-flavours or other faults. The most common contaminants are coli, yeasts, and moulds. (iii) It must be vigorous and produce acid at a brisk and steady rate. (iv) It must be capable of growing under the conditions of the particular cheesemaking process employed. For example, high scalding temperatures may render an otherwise suitable starter ineffective. (v) It should not be affected appreciably by growing in different types of milk.

Propagation of a Starter. The following recommendations are made for the farm-house and small-scale cheesemaker, but the fundamental principles apply universally.

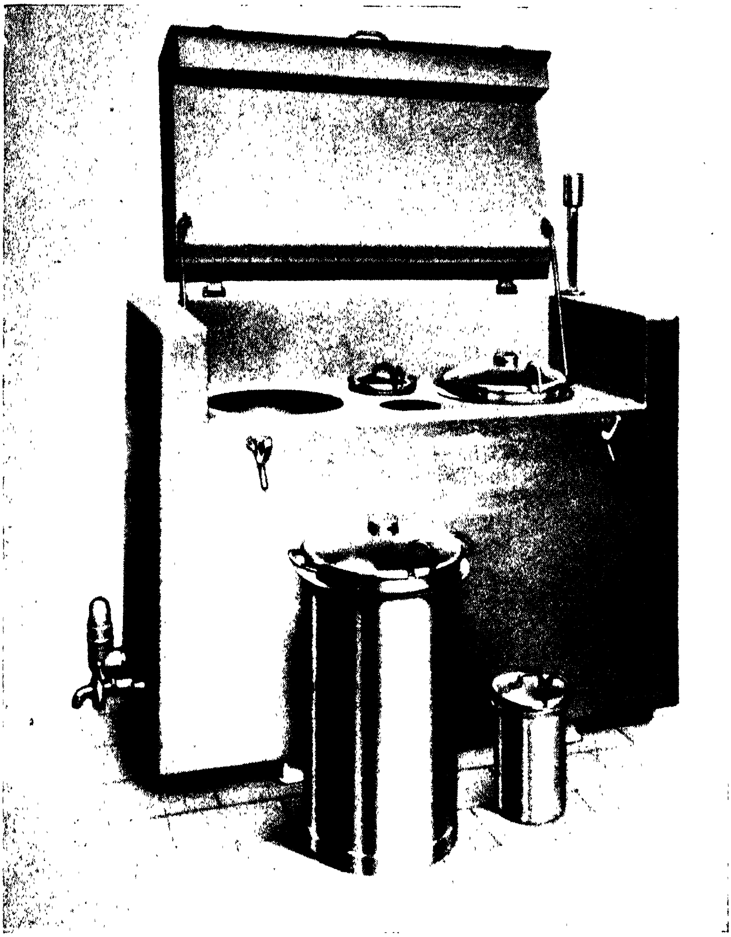
(i) ***Choice of milk.*** It has long been recognised that some types of milk are unsuitable for the growth of starter. Such milk is apparently the result of a pathological disturbance of the udder due to mastitis in some form, or other abnormal condition. The damage to the milk-secreting cells of the mammary gland results in serious defects in the chemical composition of the milk. The major differences are in the casein, calcium, and acidity, all of which may be lowered, the degree depending on the severity of the mastitis.

Also there may be a decrease or even absence of some of the vitamins or growth factors which are normally present in milk and are required for the satisfactory growth of the lactic acid bacteria.

In addition to the poor growth of starter there are two further reasons why such milk should not be used for starter-propagation or cheesemaking. First, this type of milk has usually a high bacterial content and so is likely to cause contamination in the starter and produce off-flavours in the cheese. These may not be avoided by pasteurisation, which kills only 90 to 99 per cent. of organisms in the milk. Second, it clots slowly with rennet, and, as every cheesemaker knows, slow coagulation will cause slow drainage, which invariably results in a poor cheese.

A really bad sample of milk may not only require 10 or 20 times as long to clot as ordinary milk, but may extend an inhibitory effect to good milk. It is probable that this is due to the high globulin content of the bad milk, this latter protein exerting a protective effect on the colloidal casein particles of the good milk as well as on its own casein. Thus the author has found that the admixture of 20 per cent. of a rennet-resistant milk will increase the coagulation time of normal milk by 50 per cent.

Such milk may appear quite normal to the eye. The trouble may be avoided, apart from rare exceptions, by the regular testing of the cows with bromcresol purple paper and the strip cut. Cows late in lactation react positively to the bromcresol test, but a positive bromcresol test plus clots, however small, indicates mastitis. A most useful indicator is the ordinary filter-cloth strainer. An increased deposit or slow filtration almost certainly indicates mastitis.



[*By courtesy of Hiron & Rempler Ltd.*

FIG. St 1.—*Equipment for Sterilising Milk for Starter and Incubation of Starter.*

The milk from any quarter which gives a purple colour with bromcresol purple paper or reveals clots in the foremilk should be kept separate from the cheese milk and used for other purposes, *e.g.* pig feeding. As far as is known, the deleterious effect is due solely to the chemical deficiencies and inhibitory substances in the milk. Mastitis streptococci themselves are not known to be injurious in cheesemaking.

(ii) ***Utensils.*** The best materials for containers are stainless steel, aluminium, enamelled ware, and glass. Aluminium becomes pitted, enamelled ware gets chipped, and glass, of course, gets broken. Stainless steel is therefore without question the best. Although appreciably more expensive than the other materials used, it lasts practically indefinitely, and is from every point of view a worth-while investment. Copper and copper alloys should not be used.

The best form is a jar or cylindrical container at least twice as deep as the diameter and having a smooth surface free from crevices so that it is easy to clean and sterilise (Fig. St 1). Milk should never be allowed to dry on any utensil. After cleaning, utensils should be sterilised by steaming for at least 10 min. at 210° F. Elaborate outfits are not necessary for small-scale work provided the above conditions are fulfilled. Thus an ordinary dustbin fitted with a false bottom and steam-jet makes an excellent sterilising-chest.

Any good detergent which is not injurious to the hands is an invaluable aid in keeping starter apparatus clean. For aluminium a metasilicate detergent should be used. *See* Cleaning and Sterilising ; Detergents.

(iii) ***Method of propagation.*** It is desirable that the mother culture should be cultivated in a medium as near as possible to that used in the vat, *i.e.* raw or pasteurised milk. In practice, however, this would rapidly result in a contaminated starter. To maintain a starter pure, the milk should be sterilised by heating to 210° F. for at least an hour. This introduces a problem which does not seem to be generally appreciated. The process of sterilisation produces in milk certain compounds resulting from the condensation of decomposition products of the sugar with nitrogenous substances in the milk. These act as bacterial-growth factors. This is the reason why lactic acid bacteria grow more rapidly in heated than in unheated milk. A culture that is accustomed to heated milk may find difficulty in growing in raw milk, especially if the latter is very clean or is deficient in natural vitamins and growth factors.

Now it is safer to maintain a mother culture pure in small bulk and to inoculate the starter from this, rather than to inoculate each starter in turn from the previous one. Both problems can be solved in a simple manner as follows :

A bottle or jar which has been cleaned, sterilised, and about three-quarters filled with milk is heated to 210° F. for at least 1 hr. and then cooled. It may be closed with an inverted cup, also sterilised, or any suitable stopper. A starter of guaranteed purity obtained from a reputable source is then inoculated aseptically into the milk. The use of a glass bottle or jar permits the detection of gas bubbles produced by a coli-aerogenes or other contamination. After mixing, the culture is incubated at 70° to 75° F. until clotting takes place, when it is removed to a cool place (5° to 15° C. or 40° to 60° F.). At the appropriate time, this culture is inoculated into a similar jar of sterilised milk heated to 210° F. for 1 hr., etc. This is then incubated as before. The remainder of the culture is then inoculated into the starter-can or vessel which, after cleaning and sterilising, has been three-quarters filled with milk and heated momentarily to 210° F. and then cooled to 70° to 75° F. Such milk is thus half-way between the drastically heated milk used for the mother culture and the pasteurised or raw milk in the cheese vat. It thus affords a stepping-stone for the culture to adjust itself.

In addition to the acclimatisation effect, this scheme affords the important advantage that contamination of the starter at any one stage does not mean contamination of the starter at the next stage. It is essential, of course, that the mother culture be kept pure. A skilled person is necessary for this purpose. The inoculum should be 0·1 to 1 per cent. of a culture at about 0·8 per cent. acidity. The exact acidity will vary according to experience, but should never exceed 0·9 per cent.

Contaminants of Starters. Common contaminants are all killed by heating to 210° F. for 1 hr. Contamination, therefore, implies imperfect sterilisation or carelessness in handling.

Coliforms. Two types are known, the true coli which causes off-flavours and taints, and the aerogenes type which produces gas freely and is frequently the cause of " gassy curd ". Although found in dung, the source of these contaminants is usually milk that has dried on utensils. Their presence therefore implies faulty cleaning and sterilisation. The presence of coli in dried commercial starters has, however, been reported.

Yeasts and moulds. These are found everywhere, especially on plant matter. Their presence indicates carelessness in propagation. Yeasts may produce gassiness and fruity flavours. They cannot always be detected by visual examination.

Mould spores are very easily air-borne and so moulds are very common contaminants. Being aerobic they grow only on the surface of starter ; hence the practice of skimming off the surface layer. This practice is sound provided the spoon is sterilised. The worst offender is *Oidium lactis*, and once this is established it is almost impossible to remove. This fungus is very common in whey tanks.

Of the less common contaminants, the aerobic and anaerobic spore-formers are the most important.

Aerobic spore-formers (*e.g. B. subtilis*). Their effect is variable ; thus they may stimulate or slow down starter. They are not of great significance in hard-pressed cheese on account of the lack of air and high acidities in cheese.

Anaerobes (*e.g. Cl. putrificum*). The famous " stinker fault " is due to the growth of an anaerobic spore-former in cheese. It is extremely unlikely that these anaerobes would thrive under normal conditions of starter propagation.

Testing Starters for Purity. Regular testing of starters is essential. The best way is to send the starter to a bacteriological laboratory for a proper examination. Under practical conditions, however, the following test will detect serious contamination : Add one part of 20 vol. hydrogen peroxide to one part of starter in 10 parts of water in a glass tube or bottle. Mix well and stand in a good light. The *continuous* evolution of bubbles is a sign that the starter is contaminated. A lens may with advantage be used as the bubbles may be very small. Occasional bubbles may be ignored.

If a laboratory is at hand, a loopful of starter may be smeared on a milk agar slope, which is then incubated at 30° C. (86° F.) for 3 days. A pure starter gives only fine, glistening " dew-drop " colonies. Anything else indicates contamination.

Tests of Milk for Starter Growth. If slowness is experienced, or if the cheese-maker has any reason to suspect the milk of any animal, the following simple test will give all the information that is required :

Clean and sterilise a number of ½ pint milk bottles or other small containers and nearly fill them with milk from : (i) mixed herd supply ; (ii) suspected cows (any number) ; (iii) presumed healthy cows (at least 2) ; (iv) milk from neighbouring farm free from slowness.

Duplicate (i) and (iv) for tests with a known good starter (= 1*a* and 4*a*).

Add to each bottle the same quantity of starter with a sterilised spoon, mix well and place all the bottles together in a warm place, preferably at 70° to 75° F. Note the time taken by each sample to clot.

The results may be interpreted as follows :

Findings	*Inference*	*Action*
(1) 1*a* and 4*a* normal—all others slow	Starter weak	Change starter
(2) 4 and 4*a* normal—1 and 1*a* slow	Starter O.K.—milk responsible	Test cows singly
(3) 1, 1*a*, 3, 4, and 4*a*, normal—all or some of 2 slow	Some of cows tested giving bad milk	Omit milk of these cows
(4) 1 and 1*a* slow—2, 3, 4, and 4*a* normal	Cows not tested giving bad milk	Test remaining cows

Slow Starters. By " slow starter ", also called " slow working ", " slow acidity ", or " non-acid curd ", or " non-development of acidity ", is understood any condition in cheesemaking in which normal acid development is not begun or maintained. There can be little doubt that slow working is the most serious fault in cheesemaking in England and New Zealand, and probably throughout the world. The economic consequences are not confined to the time lost in manufacture ; slow working leads to weak curds and correspondingly weak body and poor texture with its inevitable faults.

The various theories which have been advanced to explain slow starter may be set out as follows :

(1) Cause of slowness in the starter culture itself—loss of vitality for reasons not known.

(2) Cause of slowness in the milk.

- (*a*) Milk nutritionally inadequate as a medium, *e.g.* as a consequence of mastitis (dysgenic milk).
- (*b*) Conditions in milk adverse, *e.g.* too high an oxygen tension as a result of aeration.
- (*c*) Inhibiting agents present in the milk.
  - (i) Inhibiting bacteria, *e.g.* certain streptococci.
  - (ii) Bacteriostatic substances preformed in milk, *e.g.* abnormal milk.
  - (iii) Cells (leucocytes) exerting a phagocytic (devouring) action.
  - (iv) Bacteriophages
  - (v) Antibiotics, *e.g.* penicillin in milk as a consequence of injection into cows in mastitis treatment.

(3) Unsuitable cheesemaking methods, *e.g.* too high a scald temperature.

There are thus at least eight distinct causes of slow starter, which may be considered in turn.

(1) ***Spontaneous loss of vitality.*** This theory is subconsciously held by most practical cheesemakers. Thus their first action when slowness is experienced is to procure another starter. Common sense suggests that when starters secured from reputable sources all fail, the cause of the trouble is more likely to be some factor external to the starter but present in that particular farm or factory. All evidence available from our study, not only of micro-organisms, but of life generally, points to the untenability of this " natural variation " or " spontaneous weakening " theory. As far as we know, it is true to say that whenever any form of life weakens there is always an assignable cause.

(2) (***a***) ***Milk nutritionally inadequate.*** The lactic streptococci, especially *Str. cremoris*, require special foodstuffs to grow vigorously. Of these, a suitable nitrogen source (casein in milk) and indispensable " growth factors " (normally present in milk) are probably the most important. It has long been recognised that milk which is chemically altered as a result of mastitis is less suitable as a medium for lactic acid bacteria than normal milk. Not only may such milk be low in growth factors, but the casein is lowered and the albumin-globulin fraction

increased. Further, this latter fraction has been stated not to be assimilable by lactic acid bacteria, and the known ready adsorbability of such proteins on particles of colloidal casein may well seriously affect the availability of casein. Although the importance of growth factors such as bios and vitamins B_1 and B_2 for lactic acid bacteria has been emphasised, it has been found that doubling the concentration of such substances in milk had no significant effect on the rate of growth. In bulk milk, therefore, the slight lowering of the concentration of such substances as the result of mastitis would hardly be of any practical importance. Systematic study of such milks has shown that the rate of growth of starter streptococci in them is usually only slightly slower than in sound milk. It would be unlikely, therefore, that ordinary bulk mixed milk containing the usual proportion of " mastitis milk " (about 10 per cent.) would give " slow starter " from this cause alone. In practice such milk may give " slow working " one day and normal or fast acid development the next. In New Zealand no effect, other than occasional stimulation, could be attributed to mastitis milk.

A related although different aspect of possible nutritional deficiencies is that of the effect of heat on milk. It is well recognised that sterilisation, by breaking down lactose, etc., results in the formation of growth-promoting substances. Consequently, cultivation of starter in such milk, as in yeast milk, may lead to " laziness " or lack of vitality in raw or slightly heated milk. It may be desirable under such circumstances (*i.e.* making cheese from raw milk) to heat the milk for the actual starter rather less drastically than usually recommended (*e.g.* momentarily to 200° instead of for 1 hr. at 200° F.). The milk for the mother culture should, of course, be heated sufficiently to prevent contamination.

(2) (*b*) ***Adverse conditions in the milk.*** The adverse condition usually considered in this respect is aeration or an increased oxygen tension, although no reason for this is offered. The probable theory behind the idea is that the streptococci are " anaerobic " or " micro-aerophilic ", and therefore are damaged by too much oxygen, *e.g.* because of H_2O_2 formation. It would appear improbable, however, in view of the invariable presence of catalase-positive bacteria and cells (leucocytes), that this theory could account for slowness. Nevertheless, the stimulating action of high-count milk and excess numbers of cells may well be related to catalase activity.

(2) (*c*) (i) ***Slowness due to inhibiting bacteria.*** Cases have been reported from time to time of slowness due to the associated growth of such organisms as *B. subtilis*. It has been found at Shinfield that such bacteria usually stimulate the growth of lactic acid bacteria by their proteolytic action or by reducing the oxidation reduction potential (removing oxygen). Thus, so far as is known Whitehead's (1933, *BJ*, **27**, 1793) inhibiting streptococci are the only authentic organisms capable of causing slowness. Although the inhibitory substance was of a peptide nature, it has been shown that these inhibiting streptococci are powerful producers of hydrogen peroxide, so that the " aeration " theory of slowness may possibly be linked with this phenomenon. Although hydrogen peroxide is itself unstable to heat, the formation of heat stable toxic " peroxide " substances is a possibility.

That the flora of some cheese milks is inhibitory is shown by the fact that the higher the acidity developed by the natural flora of the milk, the lower is the acidity produced by the starter.

(2) (*c*) (ii) ***Bacteriostatic substances preformed in milk.*** The best-known example of this type of slowness is that described by Leitch, when small amounts of the milk from one particular cow held up the lactic acid fermentation in the cheese vat. Similar cases have not been reported since, and it is unfortunate that not more is known of the nature of this type of milk. Prouty reported that milk of *p*H 6·9 usually failed to permit good growth of *Str. lactis*. Adjustment of the *p*H to the normal value and pasteurisation at 155° F. for 30 min. sometimes improved

the milk as a medium but failed to remove entirely the inhibiting effect. As little as 10 per cent. mastitis milk in a bulk could cause retardation of growth.

(2) (*c*) (iii) ***Slowness due to the phagocytic action of leucocytes.*** The behaviour of milk containing large numbers of leucocytes ($>$ 1,000,000 per ml.) may be different in many ways from that of normal milk ($<$ 50,000 per ml.), and it is rather difficult to assess those properties which are due to the cells as these may behave differently on removal from the milk. Whitehead and Cox (1933), *JDR*, **4,** 74) found that if more than 5,000,000 leucocytes were present per ml. slow working resulted, and attributed this to the phagocytic activity of the cells. It may be assumed, however, that milk in cheese vats rarely contains over 5,000,000 leucocytes per ml. In practice, 100,000 to 1,000,000 is likely to be the figure met with, and Whitehead observed that the cells actually stimulated acid production provided that the number did not exceed 1,000,000 per ml. This stimulating effect survived pasteurisation. A correlation has also been observed between catalase figures and fast working in bulk milks.

(2) (*c*) (iv) ***Slowness due to bacteriophage action. The nature of bacteriophage.*** The bacteriophage theory of slow starter is the most recent and the most interesting, for the reason that phage has been shown to be the most common cause of the trouble in New Zealand and in England.

The term " phage " means literally *devouring*—the same root occurring in " phagocyte ". It is applied to that agent which causes a lysis or destruction of bacteria and which can be transmitted from one culture to another, just as measles can be transmitted from one human being to another. It was first observed by Twort in 1915 and independently by d'Herelle in 1917. The latter gave it its name and investigated its properties. Like bacteria and viruses, phage can regenerate itself in association with suitable strains of bacteria, *i.e.* phages are specific for bacterial strains. They are widely distributed and are most abundant in the intestinal contents of animals. Phages can be readily separated from bacteria by bacteria-retaining filters ; their size is therefore significantly less than that of bacteria. The values generally accepted are from 10 to 80 $\mu\mu$ (1 $\mu\mu = \frac{1}{1000}\,\mu = \frac{1}{10{,}000{,}000}$ cm.; *B. coli* is about 1 μ long). Like micro-organisms, viruses, and enzymes, they are destroyed by heat ; usually 30 to 60 min. at a temperature of 70° to 75° C. is sufficient to destroy phage. Dried preparations are more heat-resistant, and, generally speaking the behaviour of the heat destruction process resembles that of protein denaturation. Phages are very resistant under favourable conditions and may remain viable after drying. They are destroyed by ultra-violet light but resist dilute mercuric chloride solution. Certain dyes, such as methylene blue, may also inactivate phage when photo-sensitised. Attempts to purify phage suggest that it is a nucleo-protein and that the particle has a weight between 10^{-13} and 10^{-12} mg. Like bacteria, phage may adapt itself to conditions which normally destroy it. Although it was originally considered that the lysis of the bacterial cell was due to the proliferation of the phage, it has since been shown that lysis may occur without increase of phage, which is itself dependent on bacterial proliferation.

It is known that phage attaches itself to the living bacterial cells ; as these divide, phage multiplies. The rate of phage proliferation is greater than that of the bacteria ; consequently a point is reached at which lysis begins. Lysis is preceded by swelling of the bacteria to six or twelve times their normal size. Phage action may cause a number of variations in the properties of bacteria. Of these, it is interesting to note that slime-forming variants are resistant to all phages ; it may therefore be of economic interest to consider the possibilities of ropy strains of *Str. cremoris* as starters for cheesemaking.

Researches upon Phage. The work of Whitehead and his colleagues in New Zealand since the original discovery of phage as a cause of starter failure has opened up a completely new field of starter research. This may be traced ultimately to the endeavour of the New Zealand school to standardise starter behaviour in such a way that a predictable course of acid development in the vat and in the curd could be obtained every day. The use of selected strains (pure cultures) of lactic streptococci gave the desired uniformity, but failures in the vat (*i.e.* slowness as compared with irregular acid development) were still encountered and complete failures were more frequent still. The proof that phage action was the cause of such failures led to extensive work to find out the mode of origin of the phage and the conditions controlling its appearance. It was early observed that phaging in the mother culture was extremely rare, less rare in the bulk starter and most common in the cheese vat. The apparently haphazard appearance of phage led to the theory of " periodic sensitivity ". According to this, phaging only took place when a culture was " sensitive ". The following factors enhanced the likelihood of phage : (i) aeration of the milk before inoculation ; (ii) the use of large volumes of culture ; (iii) the use of stale (*i.e.* 4 to 5 days old) sterilised milk ; (iv) the use of certain milks.

An empirical solution to the problem was found in the use of heavy inoculations —*c.* 1 per cent. instead of *c.* 0·1 per cent. This simple alteration in technique gave remarkable results. The resultant more rapid clotting naturally led to " over-ripening ", but this did not seem to affect the activity of the vat ; excessively large inocula or prolonged incubation led to a slight lowering of activity which readily disappeared if normal conditions were restored. The same final acidity was obtained with single-strain starters independently of the size of inoculum, but above 30° some effect leading to permanent loss of activity was produced. Experiments showed that heavy inoculation did not suppress phage ; when this was added artificially the only effect of large inocula was to delay the action somewhat. It was observed that all conditions favouring phage activity also resulted in a long lag period and consequently the use of freshly heated milk, large inocula (1 to 1½ per cent.) and incubation at 24° C. (74° F.) were recommended. Failures when this procedure was followed were ultimately traced to faulty technique, *i.e.* contamination of the culture with extraneous phage. The theory that phage was carried from generation to generation in non-phaging cultures and then finally developed could not be disproved, but available evidence was against this suggestion. The importance of such contamination was emphasised when it was found that phage could frequently be recovered from the whey of a normally working vat. The latest results in New Zealand emphasise the importance of aseptic technique in starter propagation.

It might be thought that phage would cause trouble only when single-strain starters were used ; phaging of one or more strains in a mixed starter would lead to varying degrees of slowness, and New Zealand experience appears to lend support to this possibility.

Many of Whitehead's observations have been confirmed by United Dairies when using single strain starters. Thus they have been able to demonstrate the presence of phage by observation of complete lysis, by failing to obtain growth on normal media and by inoculating phage into a susceptible culture and observing the cessation of growth. The phage preparations were obtained from milk and whey by the usual filtration methods. They confirmed that these phage filtrates were strain-specific. (A point of fundamental interest in this connection is whether all strains, or only those which have been found to undergo phaging elsewhere, are susceptible.) Where single-strain *Str. cremoris* cultures had been used phage could be demonstrated in the cheese vat, starter room, and laboratory cultures. Moreover, phage was found to lower the activity of a mixed culture containing the sensitive organism. Phaging frequently occurred after clotting of the culture and in cheesemaking practice it was usually observed during the scald. It could be followed immediately by the growth of a strain resistant to the original phage. This secondary strain was in turn susceptible to an appropriate phage. A number of interesting observations on factors likely to encourage phage action was made.

Thus, when working with a strain known to be liable to phage, it was observed that certain milks encouraged phaging and that the inclusion of a small proportion of phage-encouraging milk would result in phaging of a susceptible culture.

Phaging occurred most frequently in certain districts. As in New Zealand, it is concluded that phaging is encouraged by any factor that tends to slow down the growth of the organism.

Davis and Newland (1940-42) showed that phage was a common cause of slowness in creameries in various parts of England, and that by observing the precautions recommended by Whitehead the fault could be avoided or minimised. Mattick, Nichols and Wolf (1944) also came to similar conclusions as the result of a large-scale investigation.

Whitehead and Hunter (1939, *JDR*, **10**, 403), have given details of their procedure for the isolation and purification of lactic streptococci phages. They point out that some races may attack up to four different strains; such phages are termed polyvalent. As reported by other workers, they have obtained resistant strains by prolonging incubation of lysed cultures. Further observations of interest are given by Hunter (1939, *JDR*, **10**, 464) who, working with variants obtained from " pure " cultures of *Str. cremoris*, found that sub-strains which failed to ferment lactose were still lysed by the special bacteriophage for the " pure " culture. Variability was also observed in power to produce " ropiness " in milk, response to high temperature conditions and vitality. In America, Nelson, working with strains of *Str. lactis*, has found that under certain conditions these may be inhibited by filtrates from slow cultures.

Slowness is more noticeable in factories than on farms. Cheesemakers who do not use starter are reputed never to experience slowness. This is, of course, quite understandable, because acid development under such circumstances is due solely to those contaminating organisms which can grow in the milk.

(2) (*c*) (v). The widespread use of penicillin in recent years for mastitis has resulted in a new cause of " slow starter ". Thus in one region cheesemaking was literally brought to a stop for this reason. When cows have been undergoing a course of penicillin treatment for any cause, the milk should be withheld from cheesemaking for at least 3 days after the last injection.

(3) ***Increase in scald temperatures.*** Another aspect believed by the writer to be under-estimated in importance is that scald temperatures have gradually increased during the last decades. Thus an old Dunlop cheesemaker remarked that forty years ago they scalded at 96° F. and got a firmer curd than is obtained now with a scalding temperature of 103° F. This steady decrease in firmness of the curd (if real) can be attributed perhaps to the lack of calcium in the milk. Thus it has been stated that before 1900, farmers frequently limed their land. With rising costs of liming this was reduced, with the result that to-day some land may be deficient in available lime. Many strains of *Str. cremoris* do not grow at 37° C. (98° F.) and most strains of *Str. lactis* stop growing at about 42° C. (108° F.). An increase of a few degrees in scald temperature may therefore be of great significance for the starter. Even a mixed culture containing strains of *Str. lactis* growing comfortably at 41° C. (106° F.) may be severely checked by holding at 104° to 106° F. for ½ hr. as most cheese starters are predominantly *Str. cremoris*. Dearden and Harrison (1941, *JDR*, **12**, 35) in one investigation found that the incidence of slowness was reduced when the scald temperature was lowered, so that this factor was undoubtedly of significance. Scald temperatures as high as 110° F. have been observed, and dairy thermometers are not always accurate. Errors as much as 4° F. have occurred; all cheesemakers are therefore advised to check their thermometers in the temperature range 90° to 110° F. The most convenient way is to test all new thermometers against one that has been checked against a standard and is kept specially for that purpose.

Of all the theories put forward to explain slowness in starters, those of bacteriophage action and " unsuitability " of the milk may be taken as proved. The latter term probably covers a wide range of factors; it is unwise to make categorical statements such as " mastitis milk causes slow starter ". Of these factors it appears probable that inhibiting flora and substances such as those present in certain milks are the commonest causes besides phage action. The transient nature of the fault, and the fact that conditions vary from day to day, make properly controlled investigation a matter of considerable difficulty. Attempts to correlate slowness with other factors are usually inconclusive. *See* Antibiotics; Cheese, p. 168; Lactic acid bacteria; Penicillin.

Refs.: Whitehead *et al.* (1953), *JDR*, **20**, 60; Czulak (1952), *AJDT*, **7**, 82; Meanwell and Symons (1953), *IDC*, **3**, 1109 (phage resistance); Doull and Meanwell (1953), *IDC*, **3**, 1114; Graham *et al.* (1952), *JDS*, **35**, 813 (phage); Hoyle and Nichols (1948), *JDR*, **15**, 398 (inhibiting strains); Nichols and Hoyle (1948); *JDR*, **15**, 409 (identity); Whitehead *et al.* (1952), *JGM*, **6**, 21; Czulak and Meanwell (1951), *SAB*, **14**, 1; Scott (1950), *DI*, **15**, 1260 (penicillin); Craigie (1946), *BR*, **10**, 73; Nichols and Ineson (1947), *JDR*, **15**, 99 (strain dominance); Whitehead and Hunter (1947), *JDR*, **15**, 112 (phage contamination from utensils); Whitehead and Hunter (1945), *JDR*, **14**, 64 (phage in cheesemaking); Nichols and Wolf (1945), *JDR*, **14**, 81 (phage-organism relationships), 93 (heat resistance of phages); Hunter (1944), *JDR*, **13**, 294 (phages in cheesemaking); Nichols and Wolf (1944), *JDR*, **13**, 302 (persistence and recovery of phage in cheese); Johns (1943), *JDR*, **13**, 119 (phage in cheesemaking); Hunter and Whitehead (1943), *JDR*, **13**, 123 (" non-acid " milk); Johns and Bérard (1943), *JDR*, **13**, 127 (effect of over-ripening); Hunter (1943), *JDR*, **13**, 136 (*Str. cremoris* phages).

STASSANISATION. A method of heat-treatment in which the milk is heated in very thin layers on the same principle as the H.T.-S.T. process (p. 790).

TATIONARY PHASE. The period of quiescence in a bacterial culture before active growth begins.

STATISTICAL FORMULAE. Quantities are estimated as follows from the members, $x_1, x_2, \ldots x_n$, of a random sample of n observations:

$$\text{Mean, } \bar{x} = \frac{S(x)}{n}.$$

$$\text{Mode} = \text{most frequent value.}$$

$$\text{Standard deviation, } s = \sqrt{\frac{S(x - \bar{x})^2}{n - 1}}.$$

$$\text{Standard error of mean} = \frac{s}{\sqrt{n}}.$$

$$\text{Coefficient of variation } (\%) = \frac{100s}{\bar{x}}.$$

$$\text{Range} = \text{highest value} - \text{lowest value.}$$

Quantities are estimated as follows from the members, $x_1, y_1;\ x_2, y_2;\ \ldots;\ x_n, y_n$, of a random sample of n pairs of observations:

$$\text{Correlation coefficient } r = \frac{S(x - \bar{x})\,(y - \bar{y})}{\sqrt{S(x - \bar{x})^2\, S(y - \bar{y})^2}}.$$

$$\text{Linear regression coefficient } (y \text{ on } x),\ b = \frac{S(x - \bar{x})\,(y - y)}{S(x - x)^2}.$$

$$\text{Linear regression equation } (y \text{ on } x),\ y = \bar{y} + b(x - \bar{x}).$$

Refs.: Yule and Kendall (1950), *Introduction to the Theory of Statistics*, London; Ilersic (1952), *Statistics and their Application to Commerce*.

STATUTORY INSTRUMENTS. These are made under an appropriate Act by a Minister. The control of milk and milk products during and since the war has been implemented by this means. *See* Legal aspects.

Refs.: Barton; Bell; Harvey and Hill; Richmond; Swift.

STEAM. Steam is the cheapest and most common way of transferring heat, not only in the dairy but in all industries. The pressure is directly related to the temperature (Table Se I).

TABLE Se I

Temp. ° F.	*Pressure lb./sq. in.*
212	14·696
220	17·186
230	20·780
240	24·969
250	29·825
260	35·429
270	41·858
280	49·203
290	57·556
300	67·013
310	77·68
320	89·66
330	103·06

See Autoclave.

Refs.: Badger and McCabe; Farrall.

STEAM RAISING.

Refs.: Jenkyns (1945), *Boiler Users' Guide*, London; Scott (1953), *IDC*, **3**, 923 (economy); Bell (1953), *JSDT*, **6**, 165; Duguid (1952), *JSDT*, **5**, 240; Griffiths, 245; Hurley (1952), *DI*, **17**, 518; Appleby (1951), *FIM*, 955; Hammond (1950), *DI*, **15**, 1027; Lyle (1947), *The Efficient Use of Steam*, H.M.S.O.; *LCDP*.

See also Water, boiler, control of.

STEARIC ACID. One of the major fatty acids in butter and most fats, $C_{17}H_{35}.COOH$. *See* Fatty acids.

STEARIN. Glyceryl tristearate (fat).

STERILISATION. Sterilisation may be defined as the destruction of all forms of life. In bacteriology this term is absolute but in practical dairying the word is used in the sense of virtual or *near-sterilisation*. It is then most important to kill as completely as possible all bacteria and spores which can produce faults in milk or milk products.

Bactericidal agents may be regarded as physical, chemical, or biological and can be classified as follows:

(i) **Physical.** (1) Heat. (2) Radiation, particularly ultra-violet light. (3) Cold. (4) Desiccation. (5) Electricity. (6) High-frequency sound waves. (7) Surface tension. (8) Pressure. (9) Filtration and centrifugation (mechanical removal).

(ii) **Chemical.** (10) Acids. (11) Alkalis. (12) Salts—anions. (13) Salts—cations (non-metals). (14) Halogens, particularly chlorine. (15) Heavy metals. (16) Dyes. (17) Phenols, etc. (18) Oxidising agents (other than halogens). (19) Formalin, etc.

(iii) **Biological.** (20) Bacteriophages, etc. (21) Antagonistic bacteria (22) Antagonistic moulds. (23) Antagonistic protozoa.

Of these (1), (9), (11), and (14) are commonly used in dairying for *controlled* sterilisation; (2), (4), and (10) (in nature) play an important part in practice in a highly variable and uncontrolled way; (2), (5), (6), (12), and (13) (controlled) have received some attention and show considerable promise, and (3) is commonly used as a *bacteriostatic* agent.

Of the biological factors (20) is of importance as an unwanted bactericidal agent in starters (p. 977) and (21) is always present but merely results in a change in distribution of flora. Possibly one day chemical substances produced by micro-organisms may be used on a commercial scale.

The present position is summarised in Table Ste I.

TABLE Ste I

	Milk	*Churns*	*Tanks, etc.*	*Bottles*	*Cowshed hygiene*
Heat	+	+	+	+	+
Cold	+	—	—	—	—
Centrifugation . .	+	—	—	—	—
Alkalis . . .	—	+	+	+	(+)
Cationic agents . .	—	—	—	(+)	(+)
Chlorine . . .	—	(+)	+	(+)	+

+ = in general use. (+) = used occasionally. — = not used.

See Chlorine ; Clean milk production ; Cleaning and sterilising of plant ; Detergents ; Disinfectants ; Pasteurisation ; Pasteurisation, alternatives to ; Quaternary ammonium compounds ; Sterilised milk.

Refs.: LCDP; Buchanan and Fulmer; Wilson and Miles; Eyre; McCulloch; Hughes (1948), *JSDT*, **1**, 230; Resuggan, 237.

STERILISATION OF MILK UTENSILS. Equipment for the steam sterilisation of dairy utensils is not universally available on farms. Even on those farms where it is installed, influences beyond the farmer's control, such as labour difficulties, fuel restrictions, etc., have resulted in less stringent attention to details of sterilisation and consequent deterioration in the keeping quality of the milk. It is known that hot sodium hypochlorite solutions when properly applied can be used with an efficiency equal to steam.

In an investigation by Bowyer, Fischer, Cooper-Willis, Davis, and Michaelis (1945, *SAB*, p. 57), three methods of sterilisation following preliminary washing with either hot or cold detergent solution were compared : steam, hot hypochlorite wash, and cold hypochlorite wash. Steaming served as a control, and the experiments also included comparison of hot with cold detergent solutions.

In the first and second series each churn received the same treatment throughout the experiment, churns being tested ½ hr. after treatment in the first series and 24 hr. after treatment in the second series of experiments. In the third and fourth series each churn received each treatment once only, churns being tested ½ hr. after treatment in the third series and 24 hr. after treatment in the fourth series of experiments.

Six treatments were used for cleaning and sterilising churns as follows : (i) 1 per cent. detergent solution at 120° F., followed by steam. ; (ii) 1 per cent. detergent solution at 120° F., followed by hot hypochlorite wash at 120° F. ; (iii) 1 per cent. detergent solution at 120° F., followed by cold hypochlorite wash at 65° F. (iv), (v), and (vi) as for (i), (ii), and (iii) but with detergent at 65° F. These treatments were chosen to vary the conditions to include all combinations.

The churns were then tested by the official rinse test (Min. Agric. Fish., Form C168/TPY), using Ringer containing 0·25 per cent. sodium thiosulphate, and the plates were incubated at 30° C. for 3 days (p. 228).

The results obtained in the third series showed that steam was significantly better than either cold or hot hypochlorite solution, and that churns washed mechanically were better than those treated with hot or cold detergent only. Heating the detergent gave negligible improvement (Table Sr I).

The results generally indicated that there is no marked difference between steam and hypochlorite, but steam appears to be slightly superior to hot hypochlorite and hot hypochlorite slightly superior to cold hypochlorite. There is no significant difference between hot and cold detergent (Tables Sr II and III).

It may be emphasised that the conditions of these experiments were arbitrary, and that therefore the conclusions are not necessarily applicable to treatments in commercial practice. In this work an attempt was made to use each treatment under optimal conditions. In practice, churns are not usually brushed with detergent solution for 30 sec., followed by 30 sec. efficient steaming, so that had steam and hypochlorite been compared under commercial conditions quite different results might have been obtained.

TABLE Sr I

	Mean log. count	
	Third series	*Fourth series*
(1) Cold detergent + steam	1·23	2·69
(2) Hot detergent + steam	1·23	2·73
(3) Mechanical washer	1·25	3·07
(4) Hot detergent + hot hypochlorite	1·96	2·69
(5) Cold detergent + hot hypochlorite	2·07	2·55
(6) Hot detergent + cold hypochlorite	2·46	2·51
(7) Cold detergent + cold hypochlorite	2·51	2·83
(8) Hot detergent only	3·54	—
(9) Cold detergent only	3·62	—
(10) Cold detergent + cold acid hypochlorite	—	2·70
(11) Mechanical washer	—	3·22

TABLE Sr II

RESULTS FOR ALL TREATMENTS COMBINED

	Mean log. count
(1) Cold detergent and steam	1·79
(2) Cold detergent and hot hypochlorite	1·90
(3) Mechanically washed churn taken at random	1·90
(4) Hot detergent and hot hypochlorite	1·99
(5) Hot detergent and steam	2·00
(6) Hot detergent and cold hypochlorite	2·07
(7) Cold detergent and cold hypochlorite	2·42
(8) Cold detergent and cold acid hypochlorite	2·70
(9) Hot detergent only	3·45
(10) Cold detergent only	3·62

TABLE Sr III

RESULTS FOR THIRD AND FOURTH SERIES ONLY

	Mean log. count
(1) Cold detergent and steam	1·94
(2) Hot detergent and steam	1·99
(3) Cold detergent and hot hypochlorite	2·31
(4) Hot detergent and hot hypochlorite	2·38
(5) Hot detergent and cold hypochlorite	2·49
(6) Cold detergent and cold hypochlorite	2·67
(7) Mechanical washer	2·75

Churns aged for 24 hr. after treatment showed a general deterioration in bacterial condition irrespective of the treatment, and a tendency to a levelling out of the results. It is noticeable that steam was significantly superior to hypochlorite in the third series when the churns were tested soon after treatment, but was no better in the fourth series when churns were tested 24 hr. after sterilisation. It may be considered that the latter series approximates more closely to practical conditions.

See Chlorine ; Churns ; Clean milk production ; Cleaning and sterilising.

STERILISED MILK. Sterilised milk is the name given to homogenised milk which has subsequently been subjected to a process of sterilisation by exposing the sealed bottles to an atmosphere of steam usually between 220° F. and 230° F. for a period lasting for 20 min. or ½ hr. The legal description contained in S.R. and O., No. 2032 (1947) is as follows: " ' Sterilised milk ' means homogenised milk which has been subjected to heat treatment for such time as will ensure that it can reasonably be expected to remain fit for human consumption for at least 7 days, and which is contained in a bottle (being the bottle in which it has been so heat-treated) sealed with a vacuum seal."

Commercial sterilised milk is not necessarily sterile in the strict bacteriological sense, but with good practice a high degree of sterility is obtained, and numerous examples are known of ordinary commercial sterilised milk remaining in good useable condition for periods up to 15 years, provided that the seals have not been raised. As a general rule, however, sterilised milk will keep sweet for several weeks at ordinary temperatures, and it is not customary to store sterilised milk under refrigerated conditions; this is what would be expected when the only living bacterial life consists at most of a few spores in each bottle.

Sterilised milk has a rich " creamy " appearance due to the homogenisation and heat treatment; the flavour may be described as " rich ", " nutty ", or " caramel ", and once consumers have acquired the liking for this flavour they seldom can be persuaded to use raw or pasteurised milks which seem very insipid in flavour to them. Sterilised milk is extremely economical in use in the home; in fact, it has been observed that consumers who changed from purchasing pasteurised to sterilised milk only used approximately 80 per cent. of the pasteurised milk they formerly used. Sterilised milk helps to make very fine milk puddings which seem much more creamy than those made with ordinary milk; this is in consequence of the homogenisation. Tea made with sterilised milk carries the characteristic flavour but not to an objectionable extent unless an excessive amount of milk has been used. The more even dispersion of the protein throughout the sterilised milk is probably the chief factor which contributes to its economical use, and it is for this reason that much less sterilised than ordinary milk is necessary to " colour " tea, and this reduced requirement does not provide enough of the odour and flavour which some people find nauseating. Sterilised milk should not be used for making junket, as it will not coagulate with rennet unless a small quantity of a soluble calcium salt, such as calcium chloride, is added to replace the calcium split off and precipitated during the sterilisation process.

Historical. The manufacture of sterilised milk appears to have originated about 1894 quite independently in Liverpool and in Germany. It seems probable that it was Soxhlet's scientific work in the previous decade in so heating milk in the bottle to destroy tubercular infection that gave the inspiration for this development, coupled with the very bad housing conditions which were so prevalent in cities in those days. In a very short space of time the process had spread to London, Birmingham, Wolverhampton and neighbouring towns. The demand for this new kind of milk was so keen that a salesman could appear in a strange urban district and dispose of a load of milk in the course of an afternoon; in fact, an entire round could be developed and established almost in a few hours.

The next development was the adoption of homogenisation following the patenting by Gaulin of his machine in London in 1904. This was a heaven-sent improvement and eliminated entirely the adhesion of the objectionable glue-like gelatinous mass of butterfat on the neck of the bottle. The thorough and even admixture of the fat globules throughout the milk also improved the nutritional value of the contents of each bottle, and the reduced " curd tension " made the milk more easily digestible by weak stomachs. Sterilised milk is only sold in large quantities in the more dense areas of population, such as London, Birmingham-Black Country conurbation, the Potteries, Liverpool, Manchester, and West Riding of Yorkshire and East Lancashire towns; the demand is increasing in Scotland in the Dundee and Edinburgh areas, and also at an extremely rapid rate in parts of Belgium, Holland, Luxemburg, and Cologne. It has been an article of trade as an export to trading stations and as ships' stores for many years.

The next big advance was the substitution of the Crown Cork seal in place of the " swing porcelain rubber-gasketed " stopper about 1930. The significance of this advance was fundamental, because it opened the way to the use of completely automatic bottle washing, the subsequent mechanical filling and sealing of bottles, and finally the automatic mechanical sterilising in the continuous sterilising machines—the bottles being moved on slat conveyors as required between the different machines.

Bottles and plant. *Bottles.* The type of bottle used is very similar in all areas, being made to contain a pint or half litre according to country. The capacities of the actual bottles are actually much larger as an " expansion space " amounting to 7½ per cent., or even 10 per cent. of the contents is required so that the milk can expand during the sterilising process without bursting the bottles. The crown cork seal is of standard size wherever used and fits a sealing rim 26 mm. across at the widest part. The control of the mechanical filling operation is one requiring both care and experience. The use of machines for filling bottles with filling valves of the sleeve type was soon discontinued, and filling machines of the " vacuum " type are now used universally for all but small-scale operation. The adjustment must be such that the level of the milk filled into the bottles is not less than 1 pint (preferably between 20 and $20\frac{3}{16}$ fluid oz.) after processing and cooling to 60° F. at which temperature the check should be made. It will be understood, therefore, that all the bottles for sterilised milk in one dairy should be of one determined height with small tolerance, and that the selected filling height should be at a known and specified depth below the overall height of the bottle, and it also follows that the filling height should be a constant measurement above a plane surface on which the bottle may be stood. These points are of very great importance if bottles for sterilised milk are obtained from several bottle manufacturers. A few critical measurements for the pint size of sterilised milk bottles are as follows, and represent the bottle devised from the mean measurements of bottles used in the Midlands:

External diameter 4 in. from base	73 mm.
Overall height	261 mm.
Filling level for accurate pint at 60° F.	
(*a*) from base (plane surface)	174 mm.
(*b*) from top of sealing ring	87 mm.
Weight	17½ oz.

Plant for small operators. In these cases the dairyman is probably already processing and bottling pasteurised milk, and he may well desire to start the production of sterilised milk in a small way before committing himself to any great expense. If in addition there is available plant for homogenising ice cream mix or other products, then little additional outlay would be required. The procedure would be to withdraw a supply of hot milk from the pasteurising plant, pass it through the homogeniser at an operating pressure of 2500 lb. per sq. in., and then to a simple appliance for the filling of clean hot bottles; this appliance would normally be of low cost, and operated on a syphon principle which would fill the required quantity of milk into the bottles up to the same level of the milk in the tank of the appliance. The Crown Cork type of seal would then be applied either by a manually operated or a semi-automatic machine.

The sealed bottles of hot homogenised milk are then placed in the crates in which they will remain until sold, and the crates of bottles are placed in rectangular tanks (say 10 ft. × 4 ft. × 3 ft.) on a false perforated bottom covering the pipes leading in the steam and water. These tanks are of robust construction to withstand pressure, and should be examined in accordance with the Factory Act, 1937.

As soon as possible after sealing, the bottles should be placed in the tanks and either covered with hot water, which is raised in temperature to approximately 210° F. by the admission of steam, prior to the cover being screwed down and the subsequent further admission of steam under pressure or, alternatively, the cover is affixed immediately and steam added to a pressure of from 4 to 8 lb. per sq. in. for a period of 20 or 30 min. It is desirable to allow the steam to escape to the atmosphere for a brief period when steam is first admitted, and where water is not used, so as to sweep out the air and avoid the formation of any cool zones in the sterilising tank which would preclude satisfactory sterilisation of the milk in such a zone.

After the sterilising period has been completed, the steam under pressure is permitted to discharge to air, the lid of the tank is raised—usually with the assistance of counter-balancing weights—and after the steam has been dissipated the crates are removed and the next batch of bottles is inserted. It is not necessary to cool the bottles of milk at this stage, although it is sometimes practised where water is used during the sterilising process, but it should be pointed out that it is not good practice to stack crates of hot sterilised milk in such large piles prior to despatch that the milk in the centre takes a long time to cool. It is under conditions such as these that spoilage can take place if thermophilic spore-forming bacteria have survived the heating process. With a simple plant of this type a battery of five or six tanks can ensure continuous operation of the homogeniser, and the filling and sealing machinery for the bottles, but an objection to this method—as to any tank method—is the hot humid atmosphere arising from the escape of so much steam into the building and which is harmful to the building and possibly to the health of the workers.

Plant for large-scale operators. In the case of large-scale operators there is need first of all to install a plant for the treatment and initial heating of the milk to be used; and then a choice as to whether a battery of large steam chests will be used for the sterilisation process, or the automatic mechanical sterilising plant which enables a much better atmosphere to be maintained in the dairy; and a better method of mechanical handling of the bottles and crates to be attained.

In both methods the plant for the treatment and initial heating of the milk could be similar in that the raw milk would be received either in cans or road tankers, and checked for quantity and quality as for pasteurised milk. The milk would then be heated to about 110° F.—usually in a plate heater—subjected to filtration or clarification by centrifugal means, and next heated to a temperature of about 160° F. before being collected in a balance tank. The milk is then homogenised at a pressure of about 2500 lb. per sq. in., which raises the temperature somewhat higher owing to the mechanical " work " done on the milk, and then usually collected in a large elevated balance tank prior to the bottling operation. It should be pointed out at this stage that some operators prefer to clarify the milk to reduce the possibility of a fine brown sediment of leucocytes and cellular debris forming in the finished bottles, but there are operators who have used filtration quite satisfactorily for many years. While the milk has been subjected to heating, cleaning and homogenisation the bottles to contain it are subjected to a thorough cleaning, usually in a hydro-soaker type of bottle washer. The bottles are discharged hot at a temperature of approximately 160° F. at which they are quickly conveyed to the vacuum-filling and Crown Cork-sealing machinery. It is at this point that the divergence of method begins and the bottles are either placed in crates at this point for sterilisation by the boiler or

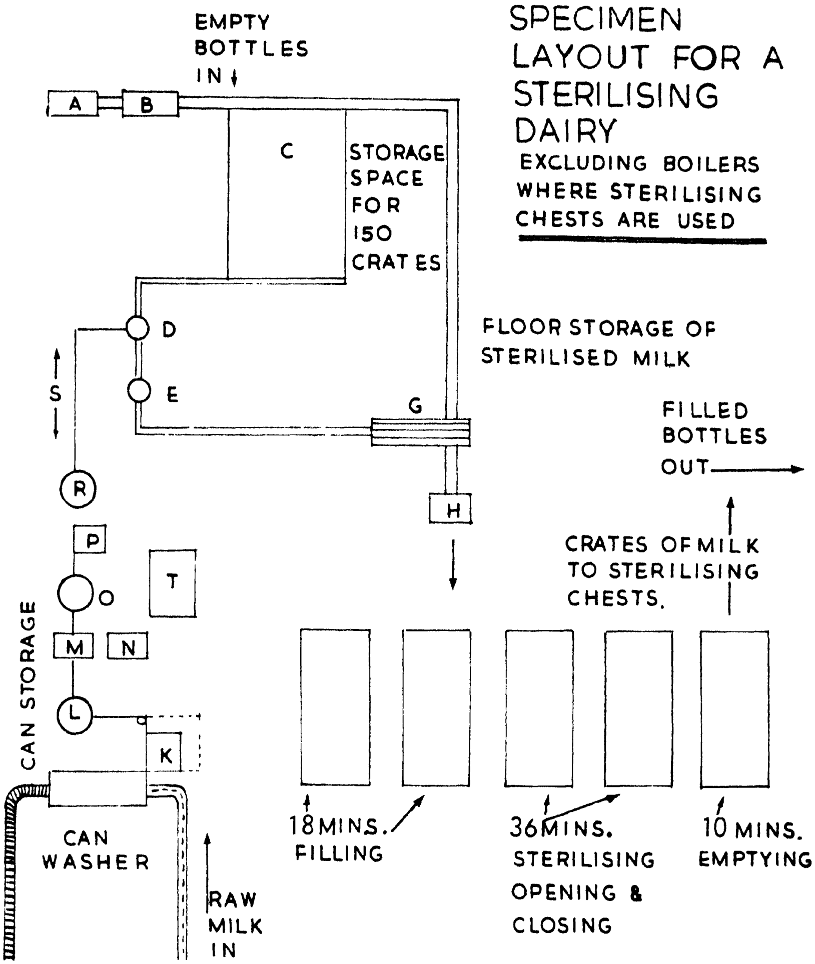

SPECIMEN LAYOUT FOR A STERILISING DAIRY
EXCLUDING BOILERS WHERE STERILISING CHESTS ARE USED
EMPTY BOTTLES IN
A
B
C
STORAGE SPACE FOR 150 CRATES
D
E
G
H
S
R
P
O
T
M
N
L
K
CAN STORAGE
CAN WASHER
RAW MILK IN
FLOOR STORAGE OF STERILISED MILK
FILLED BOTTLES OUT
CRATES OF MILK TO STERILISING CHESTS.
18 MINS. FILLING
36 MINS. STERILISING OPENING & CLOSING
10 MINS. EMPTYING

FIG. Si 1.—*A. Uncrating Machine. B. Unscrambling Machine. C. Soaker Bottle-washing Machine. D. Bottle Fillers. E. Crown Cork-sealing Machine. G. Crating Machine. H. Crate Stacking Appliance or Point. K. Raw Milk Weigh Tank (balance tank under). L. Store Tank for Raw Milk. M. Preheater and Heater for Milk. N. Milk Filter or Clarifier. O. Intermediate Balance Tank. P. Homogeniser. R. Balance Tank for Hot Homogenised Milk. S. Sanitary Pipe Line Conveying Hot Homogenised Milk to Bottle-filling Machine. T. Hot Water Set for Milk Heaters M.* GENERAL NOTE.—*Dairy to be built on ground level to permit use of fork trucks inside dairy and to facilitate loading of heavy lorries with milk for transport to distributive depots.*

steam-chest method, or are mechanically conveyed to the automatic feed-in machinery of the mechanical sterilising machinery of which the Webster "Pioneer" Machine is in universal use in Britain. The two methods will be described separately as follows:

(1) THE TANK OR BOILER METHOD. The tanks used are really a larger edition of those used by the smaller operators. The boilers are cylindrical in shape and in Britain are often referred to as Cradley boilers; they are fitted with an easy and quick-fastening type of door at one end, and a floor is so fitted to assist the loading and unloading of the steriliser, and a ramp completes the list of more important fittings. Other attachments include a pressure gauge, safety valve, and steam release valve. A battery of 5 or 6 such tanks will provide for continuous operation of the milk processing and bottle-filling equipment.

The stacks of bottles are assembled on stillages or pallets and conveyed up the ramp into the tank by a hand truck. When the doors are closed the steam is turned on while the steam release cock or stop valve is open, but as soon as the air has been forced out the steam release cock is closed. The bottles are subjected to treatment for the selected combination of time and temperature—say 230° F. for 30 min., after which the steam is turned off, and then the steam release cock can be gently opened so as to reduce the pressure of steam to that of the atmosphere when the doors can be opened and the pallets of bottles removed. The next batch can then be inserted.

The advantages of this method are the less capital cost, the lower cost of maintenance, and the flexibility of operation by the selection of different combinations of time and temperature for the milk sterilisation. The disadvantages include the hot, humid atmosphere of the dairy caused by the constant release of steam from the tanks, and also that much more costly manual work is involved in the movement of bottles compared with the use of the automatic continuous type of mechanical steriliser. Fig. Si 1 sets out a modern arrangement of plant suitable for this method.

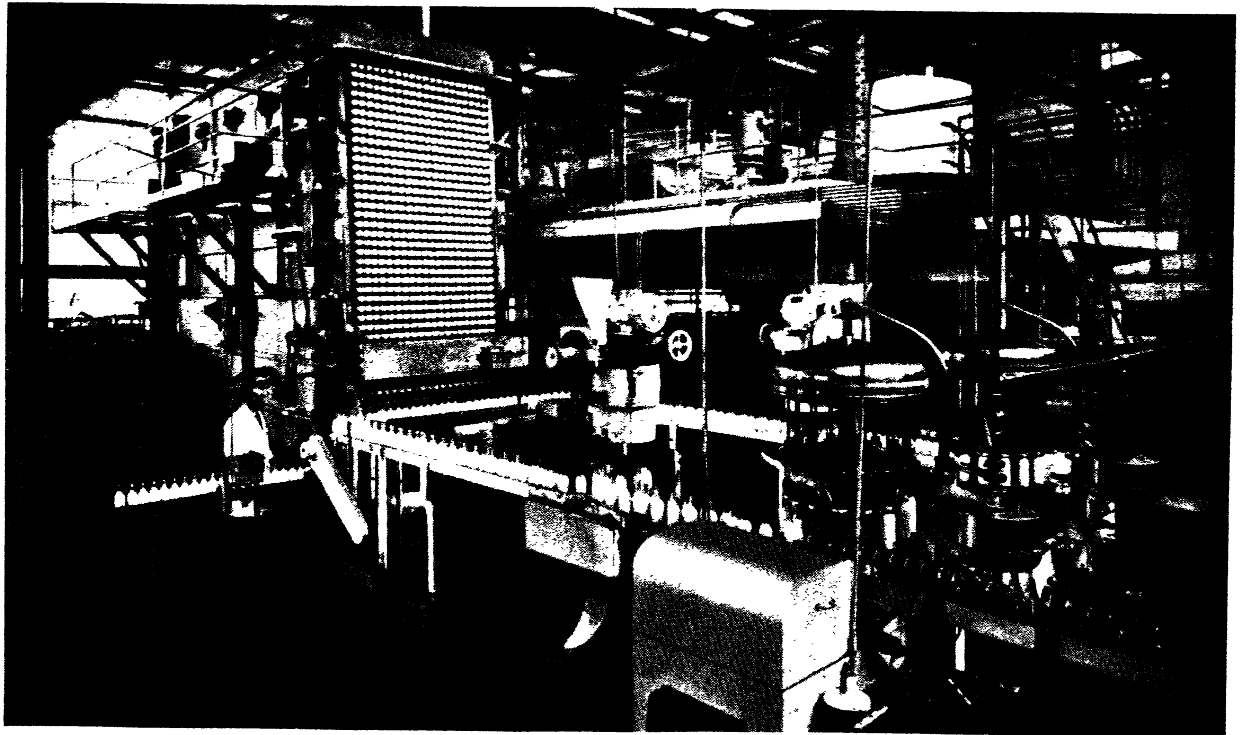
(2) CONTINUOUS MECHANICAL STERILISATION. Continuous automatic sterilisers have a number of technical as well as practical advantages over batch and semi-automatic processes, amongst which are: (i) Uniformity of taste and appearance due to unvarying temperature and time control. (ii) Superior keeping qualities owing to immediate and controlled cooling after processing. (iii) Freedom from " milk skin " due to the movement of the milk during processing. (iv) Saving in handling costs and resultant breakages. (v) Reduced breakage in processing due to controlled heating and cooling.

Modifications have been made to the treatment times and temperatures in the latest types of continuous steriliser in order to conform to variations in general practice, and machines are now designed to give either 30 min. holding at 226° F. (108° C.) or in the high-temperature sterilisers holding times of up to 44 min. at 230° F. (110° C.). For the high-temperature sterilisers an alternative lower temperature of 226° F. and a reduced holding time can also be used by simple adjustment and the machine adapted for the sterilisation of cream in varying bottle sizes.

In the continuous automatic sterilising process the milk is cleaned and preheated in the normal way prior to homogenising at a temperature of 160° F., the homogenising pressure being generally in the region of 2500 lb. per sq. in.

The homogenised hot milk is generally passed to the filling machine either direct from the homogeniser or by way of a balance tank and filled into hot bottles which are delivered from the bottle-washing machines at a temperature of about 160° F. Immediately after filling, the bottles are Crown corked and passed by conveyer chain direct to the loading mechanism of the steriliser, so that the bottles enter the steriliser at approximately 160° F.

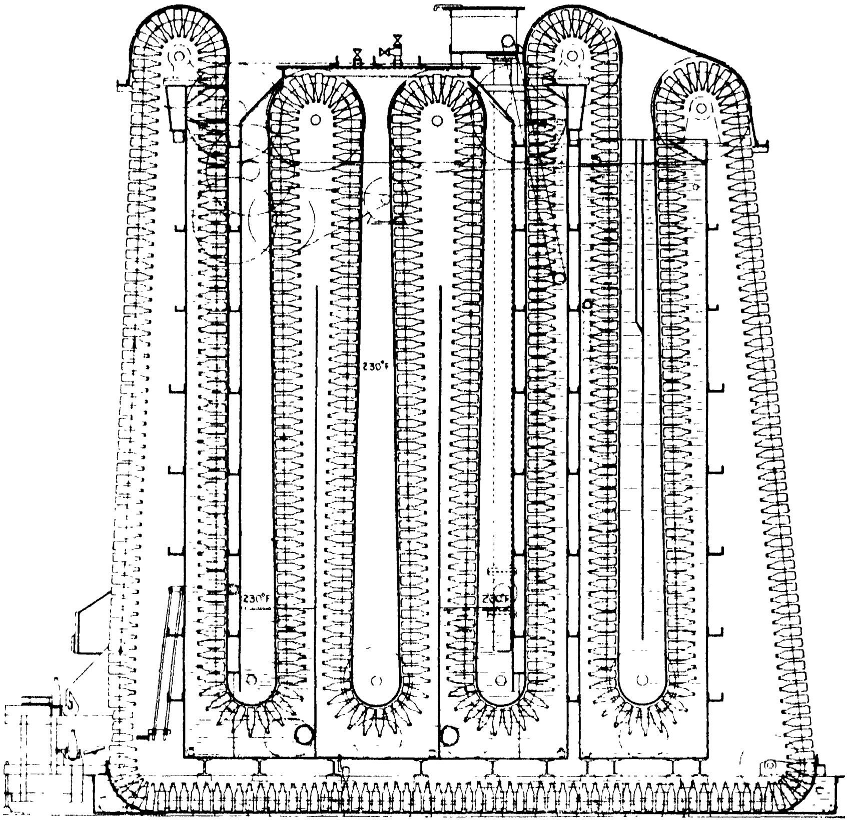
In general, the bottle carriers of the continuous automatic sterilisers are either 14 or 20 bottles wide, the bottles being carried round the machine in carrier



[By courtesy of Birmingham Co-operative Society.

FIG. Si 3.—*Sterilising Plant in Operation.*

" pockets ". The carriers travel through the machine, attached to two continuous chains which are driven at five separate points at the top of each chain loop so that an even steady movement is obtained (Fig. Si 2).



[*By courtesy of R. W. Webster Ltd.*

FIG. Si 2.—*Pioneer Totally Automatic Continuous Steriliser* (230° F.)

The arrangement of the continuous steriliser depends on the plant layout of the dairy, the machine being capable of arrangement either for single floor or two-floor operation (Fig. Si 3).

In operation, the continuous steriliser takes the bottles from the conveyor connecting from the filler and Crown corking machines and spaces out either 14 or 20 bottles by means of a star wheel. The bottles are pushed on to, and gently laid on their sides in, turnover cradles, steel fingers inserting the bottles into the carrier pockets in which they travel through the various heating and cooling zones of the steriliser.

The carriers after being loaded with the bottles of milk at approximately 160° F., travel upwards to the top of the machine through a hooded section, warmed to maintain the temperature of the hot milk, and enter the first heating tank in which the water is held at 212° F. This tank, together with a similar tank at the other end of the holding chamber, acts as a water seal, and is of

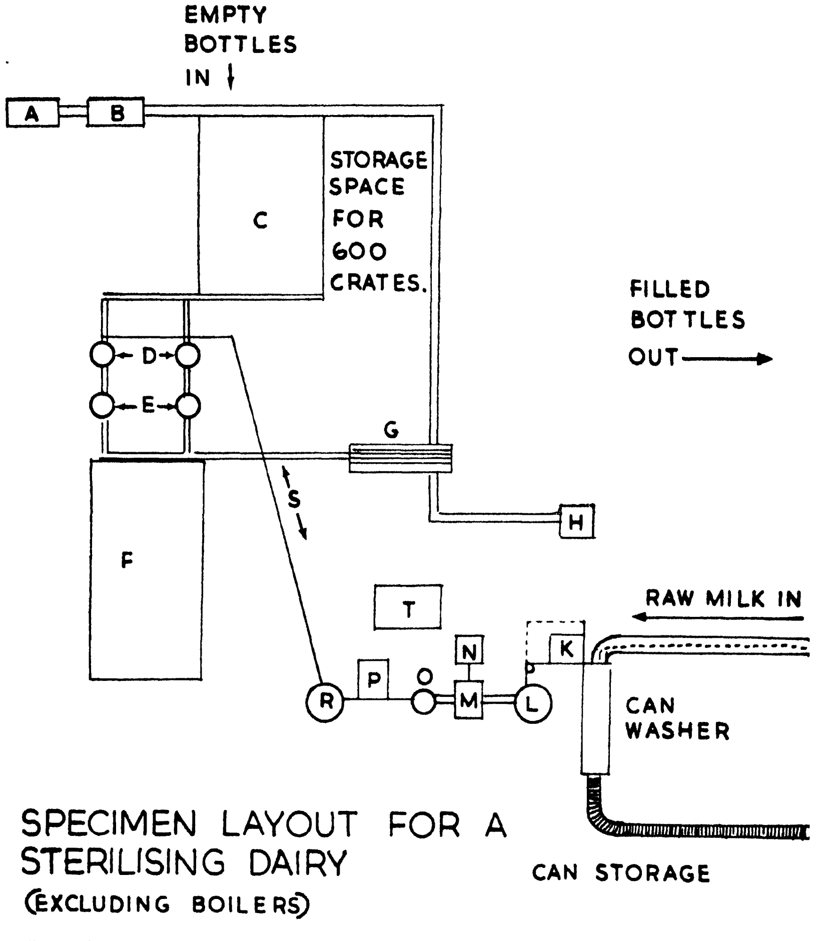


FIG. Si 4.—*A. Uncrating Machine. B. Unscrambling Machine. C. Soaker Bottle-washing Machine. D. Bottle Fillers. E. Crown Cork-sealing Machine. F. Automatic Continuous Sterilising Machine. G. Crating Machine. H. Crate Stacking Appliance or Point. K. Raw Milk Weigh Tank (balance tank under). L. Store Tank for Raw Milk. M. Preheater and Heater for Milk. N. Milk Filter or Clarifier. O. Intermediate Balance Tank. P. Homogeniser. R. Balance Tank for Hot Homogenised Milk. S. Sanitary Pipe Line Conveying Hot Homogenised Milk to Bottle-filling Machine. T. Hot Water Set for Milk Heater M.* GENERAL NOTE.—*Dairy to be built on ground level to permit use of fork trucks inside dairy and to facilitate loading of heavy lorries with milk for transport to distributive depots.*

sufficient height to maintain the steam pressure in the closed holding tank necessary for the sterilising temperature. To obtain temperatures of 226° to 230° F. the steam in the holding chamber has to be at a pressure of approximately 4¼ or 6 lb. per sq. in., and to obtain these pressures a difference in water level of from 10 to 14 ft. is maintained in the water seals.

After descending through the ingoing water seal at 212° F. the bottles enter the sterilising zone through a short water section at a temperature of approximately 220° F., and from this pass direct into the pressure steam zone, where they are held at either 226° or 230° F. for a pre-determined holding time.

The bottles then pass from the sterilising zone through a short water section and up through the outgoing water seal, the temperature of which will again be approximately 212° F.

From the outgoing seal the bottles pass to the first cooling tank which is partitioned so that a flow of water may be produced through it against the advancing stream of bottles.

In order to obtain gradual cooling, the top of the cooling tank is warmed when first starting up the machine until a regular flow of hot bottles passes from the outgoing water seal; thereafter the steam is thermostatically shut off from the ingoing side of the cooling tank, and a small supply of cool water introduced at the outgoing end of the tank so that the bottles advance against this cooling stream.

After the first cooling tank the bottles descend the back of the steriliser to the second cooling tank, which forms the base of the machine where the bottles are totally submerged in cooling water which is kept constantly overflowing by the admission of cold water at the discharge end; the warm overflow water is then passed to the preliminary cooling tank.

After cooling, the bottles are automatically discharged on to a conveyor chain leading them to any convenient point for packing into crates.

Fig. Si 4 represents a suitable modern layout for a plant for the continuous automatic sterilisation of milk.

Tests for Sterilised Milk. One of the most useful tests is the determination of the bacterial count. As properly produced sterilised milk is sterile or near-sterile, it is good practice to provide a pre-incubation period of the milk of one or two days at average room temperature. If a search is to be made for thermophilic bacteria, the incubation should be at 55° or 63° C.

The phosphatase test is not applicable to sterilised milk, because the heat degradation substances appear to increase the intensity of the blue colour produced in the Kay and Graham test, and so erroneously indicate under-heating of the milk.

The official test is the turbidity test devised by Aschaffenburg, and the principle is to check the amount of heat applied by testing for heat coagulable proteins. When 5·0 ml. from the total filtrate obtained by adding 4 gm. of ammonium sulphate to 20 ml. of sterilised milk is perfectly clear after immersion in boiling water for 5 min., the interpretation is that the sterilised milk was heated at least to boiling point for several minutes (Aschaffenburg, 1950; S.I. (1949), No. 1589. *See* also Burton (1954); Fellows (1953)).

Great care should be taken to ensure that the raw milk supplies prior to sterilisation are not constantly and heavily contaminated with spore-forming bacteria. When present the spores quickly develop into bacteria during hot weather and cause reduced keeping quality by premature curdling, or off-flavours and odours —frequently suggestive of a ketonic character. When such troubles become established they are usually very difficult to eliminate, and the objective should be to prevent their appearance.

Faults. One of the commonest is a brown deposit which may be caused by the precipitation of calcium-phosphate or of epithelial or other cells, the precipitate absorbing brown colouring matter formed by the heating process.

Bacteriological problems The chief bacteriological fault is sweet curdling frequently due to highly resistant spores of *B. subtilis* and *B. cereus* (Morgan, 1943). The serious fault known as " carbolic taint " is due to breakdown of tyrosine, etc., by similar organisms (Hiscox and Christian, 1931). Other taints such as bitter, " bad egg ", and " oxidised " or " cardboard " flavours, may be due to the growth of *B. subtilis*, *B. thermoacidurans*, and *B. circulans*.

The production under commercial conditions of sterilised milk of consistently high quality calls for a close and good working association between the laboratory and the dairy. This is necessary so as to reduce or eliminate spoilage caused by the survival of spores of heat-resistant bacilli—usually of aerobic or micro-aerophilic type. The species which most commonly cause trouble are *B. subtilis*, *B. cereus*, *B. mesentericus*, *B. mycoides*, *B. circulans*, *B. megatherium*, *B. licheniformis* and intermediate types. These bacilli are commonly associated with soil and cow byres, and if the spores survive the heating process, they can cause spoilage under ordinary summer temperatures.

Recently Clegg (1950) has described the results of his researches into the less common spoilage of sterilised milk caused by such thermophilic spore-forming bacilli as *B. calidolactis* and *B. coagulans* (*thermoacidurans*). These bacilli are reported to cause spoilage when sterilised milk is maintained at a higher temperature than usual, *e.g.* when sterilised milk is not promptly cooled when removed from the boiler type of steriliser, and is held overnight in a confined space which does not permit of rapid or sufficient cooling. These are conditions which would not apply in all dairies where sterilised milk is processed.

Changes in Milk Affected by Sterilisation and Homogenisation. These may be summarised as follows:

(i) The fat globules are broken down so that at least 75 per cent. are less than $1{\cdot}5\mu$ in diameter $\left(1\mu = \frac{1}{10{,}000}\text{ cm.}\right)$.

(ii) The sugar and proteins are changed to produce caramel substances and sulphydryl compounds. These exert an anti-oxidant role, and so the fat in sterilised milk is less liable to develop oxidised taints.

(iii) The enzyme lipase is destroyed, and this also reduces the factors likely to affect the fat.

(iv) Half the vitamin C and 30 per cent. of the vitamin B_1 are destroyed. Vitamins A and B_2 and carotene are unaffected. The biological value of the protein is slightly reduced (Kon, 1944).

(v) The " curd tension " of the milk is considerably reduced, so that sterilised milk becomes " soft curd milk ". Such milk is often more easily digested by children and invalids.

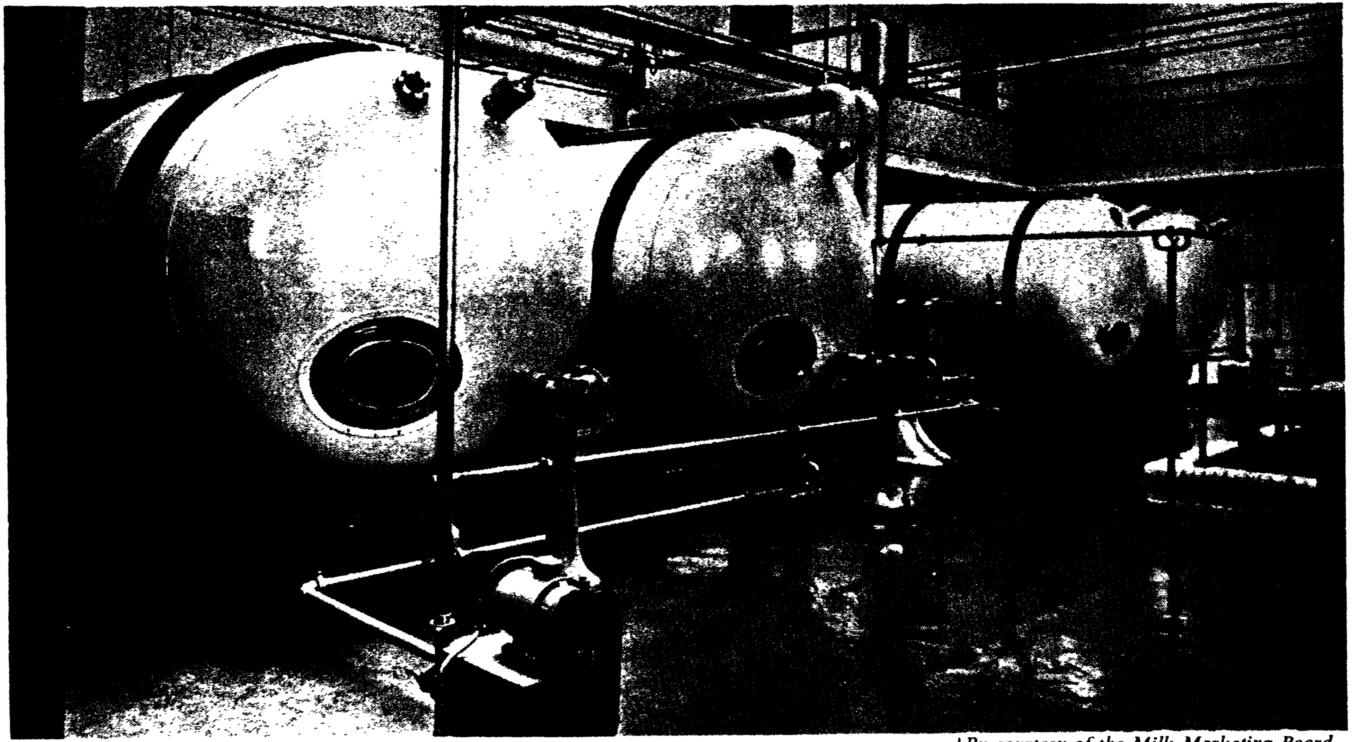
(vi) All non-sporing bacteria and the vegetative cells of spore-formers are destroyed. Spores may survive, but good quality raw milk properly processed and kept from recontamination may last for months, and even years, after the sterilisation process.

Some manufacturers of sterilised milk are adopting a high temperature-short time system of flash pre-sterilisation in continuous flow to temperatures of about 275° F. (135° C.) for the purpose of destroying all spores. After bottling and sealing, the milk is subjected to sterilisation processes similar to those already described.

There is a great need for a test of the heat-treatment which has been applied to sterilised milk, and Fellows (1953, *DI*, **18**, 309) has described a method which may be considered for this purpose. However, further work is necessary before any test can be accepted for the purpose.

See Homogenisation; Nutritive value; Stability, microbiological; Sweet curdling; Thermoduric bacteria; Thermophilic bacteria.

Refs.: Procter (1947), *DI*, **12**, 642; Reid (1945), *DI*, **10**, 561; Mould (1945), *DI*, **10**, 330; McKenzie (1945), *DI*, **10**, 334; Procter (1943), *DI*, **8**, 275; Aschaffenburg



[*By courtesy of the Milk Marketing Board.*

IG. So 1.—*Stainless Steel Storage Tanks of* 3000 *gal. capacity.*

(1950), *JSDT*, **3**, 236; Procter (1949), *D*, **66**, 495; Clegg (1950), *JSDT*, **3**, 238; Keeling (1950), *JSDT*, **3**, 264; Procter (1951), *JSDT*, **4**, 107; Procter (1951), *JSDT*, **5**, 26; Kon (1944), *Proc. Nut. Soc.*, **2**, 154; Burton *et al.* (1953), *JSDT*, **6**, 98 (batch method); Anon (1952), *DI*, **17**, 417; Thiel and Burton (1951), *JDR*, **18**, 251; Procter (1953), *D*—, ; Fellows (1953), *DI*, **18**, 309; Burton (1954), *JDR*, **21**, 194; Mohler (1952), *Chimia*, **6**, 212; Lang (1953), *DI*, **18**, 678.

STERILITY TESTS FOR DAIRY EQUIPMENT. A given area, *e.g.* 1 sq. ft. or one item, *e.g.* a cock, may be swabbed and the Ringer solution then plated in the usual way. The suggested standard is not more than 5000 colonies per sq. ft.

Refs.: Min. Agric. (1944), Form C, 195/TPY; *LCDP;* Lindqvist and Anderson (1953), *IDC*, **3**, 887 (contact plate); Thomas *et al.* (1952), *DI*, **17**, 607; Tredinnick and Tucker (1951), *SAB*, **14**, 85 (alginate swabs); Higgins (1950), *MBMH*, **9**, 50; Egdell and Bird (1950), *DI*, **15**, 511 (thermodurics).

STEROLS. Higher alcohols containing aromatic rings and of great biological importance as irradiation of some sterols leads to the formation of vitamin D.

STEWART-SLACK METHOD FOR BODY CELLS IN MILK. Two ml. of milk are centrifuged in a tube stoppered at each end. The sediment is spread over 4 sq. cm., stained with methylene blue and counted in the usual way.

Ref.: SMDP.

STILTON. *See* Cheese, p. 201.

"STILTON." A trade name for a small size of cheese, usually 10 to 12 lb., and applied to Cheddar and other varieties.

STIRK. A heifer less than two years old.

STOKES' LAW. The rate (v) at which a rigid neutral sphere of density Δ and radius r will rise or fall through a viscous fluid of viscosity η and density ρ can easily be shown on purely dimensional grounds to be proportional to $r^2(\Delta-\rho)g/\eta$, where g is the acceleration of gravity. The proportionality constant is much more difficult to calculate but is, in fact, 2/9.

For real materials the law does not generally hold very precisely because the particles are not spheres, often bear electric charges and, as with fat globules in milk, are themselves not rigid. Various corrections have been made in the original equation to allow for these modifications. *See* Cream line; Fat globules.

STORAGE TANKS. These are essentially the same as tankers but are permanently fixed in creameries or pasteurising depots. Fig. So 1 illustrates a modern type of stainless steel insulated storage tank. *See* Management of creameries, of pasteurising depots; Tankers.

STORCH REACTION. *See* Peroxidase.

"STORMY FERMENTATION" TEST. A test for the presence of *Cl. butyricum*, etc., made by heating milk in a tube to 80° C. for 10 min. under a seal of vaseline, etc., and incubating at 37° C. for some days. A typical torn and blown curd, often with a pinkish colour, and smelling of butyric acid indicates a positive reaction.

STRACCHINO. *See* Cheese, p. 203.

STRAINING OF MILK. The removal of visible dirt by passing milk through a muslin cloth or cotton wool pad. *See* Sediment test.

"STRAYS", "STRANGERS", "ROGUES", "FOREIGNERS". Trade names for bottles of different design, especially in relation to size of neck. With certain types of filling machines, a "strange" bottle may be broken and splinters of glass will fly in all directions. It is therefore a matter of considerable importance that such bottles be detected and removed.

STREPTOCOCCUS. *See* Classification; Haemolytic streptococci; Lactic acid bacteria.

STREPTOTHRIX. An old name for a group of higher bacteria now incorporated into the genera of *Actinomyces* (p. 11) and *Fusiformis*.

Refs.: Bergey; Wilson and Miles.

STRIKING POINT. *See* Condensed milk.

STRINGY MILK. *See* Ropy milk.

STRIP METHOD FOR COLONY COUNTS.

Refs.: Stirling *et al.* (1950) *JGM*, **4**, 339; Higginbottom (1953), *SAB*, **16**, 16; George *et al.* (1953), *LP*, **2**, 294.

STRUCTURE OF MILK. Milk apart from cells and bacteria consists of: (i) a serum containing lactose, salts and albumin and globulin; (ii) fat globules; (iii) solid particles in a colloidal or finely-divided condition consisting of casein and attached calcium phosphate. *See* Colloids; Constituents.

Refs.: Rogers; Hostettler and Imhof (1951), *M*, **6**, 351, 400.

SUBLIMATION. The vaporisation and condensation of a substance without passing through a liquid phase.

SUCCULENT FEEDS. *See* Feeding.

SUCTION. The creation of a partial vacuum. Water cannot be raised more than 34 ft. by suction.

SUGARS. Organic substances of the general formula $C_nH_{2n}O_n$ thus containing carbon, and hydrogen and oxygen in the proportion in which they occur in water, hence the term carbohydrates. The common sugars have 6 or 12 carbon atoms and are termed hexoses or monosaccharides, and disaccharides.

The ability of micro-organisms to ferment (produce acid or acid and gas in) various sugars is one of the chief characteristics used for identification purposes.

See Carbohydrates; Classification; Coliforms; Glucose; Lactic acid bacteria; Lactose.

Ref.: Bergey.

SULPHATED FATTY ALCOHOLS. Alcohols in which the sulphate radicle —O—SO_2O— has been introduced. The combination of hydrophobic (fatty) and hydrophilic (sulphate) groups gives these substances surface-active properties and hence their value as wetting agents. *See* Detergents.

SULPHYDRYL COMPOUNDS. When milk is heated to 80° C. or higher, sulphydryl (— SH) groups become liberated to give reducing properties and a characteristic smell. *See* Heat, effect on milk.

Ref.: Larson and Jenness (1950), *JDS*, **33**, 890.

SUNLIGHT. Sunlight is a mixture of radiations of various wave-lengths. The following aspects are of interest in dairying: (i) the killing of bacteria when unprotected by organic matter (*see* Disinfection); (ii) the acceleration of dye reduction tests (*see* Methylene blue and Resazurin tests); (iii) the formation of vitamin D in the skins of dairy cattle by irradiation of sterols in the tissues; (iv) the destruction of vitamin C in bottled milk. *See* Nutritive value.

SUNLIGHT FLAVOUR. A peculiar flavour in milk catalysed by sunlight and unknown in this country.

Refs.: Weinstein *et al.* (1951), *JDS*, **34**, 784; Weinstein and Trout (1951), *JDS*, **34**, 554, 559, 565; Weinstein *et al* (1951), *JDS*, **34**, 570.

SUPER-COOLING. The cooling of milk below the actual freezing-point to obtain separation of ice. *See* Freezing-point test.

SUPER CREAM, SOLID CREAM. Cream of about 75 per cent. fat. The economy in storage and transport makes this convenient for special purposes, *e.g.* ice cream in the old days.

SUPER-HEATING. A treatment sometimes applied in making evaporated milk (p. 277). *See* Sterilised milk (p. 998); Uperisation.

SUPPLEE'S METHOD. *See* Solubility of milk powder.

SUPPURATION. The formation of pus.

SURFACE ACTIVITY. *See* Adsorption; Detergents; Quaternary ammonium compounds.

Ref.: Glassman (1948), *Bact. Rev.*, **12**, 105.

SURFACE TENSION. The forces acting on the molecules in the body of a liquid are normally balanced. At the surface, however, the forces attracting the molecules inwards are not balanced, so that any attempt to break the surface requires that work shall be done. The force required to break 1 cm. of surface is called the surface tension.[1] The popular analogy between the surface and an elastic membrane is misleading, because the latter would require for its displacement a force increasing in proportion to the amount of displacement, which is not the case with liquid surfaces.

Molecules which are surface-active, *i.e.* alter the surface tension of liquids in which they dissolve, tend to collect at (adsorption, *q.v.*) or to shun the surface. In certain cases, very small quantities of surface-active materials will greatly alter the surface tension of a liquid. Aschaffenburg (1946, *JDR*, **14**, 316) has found that it is the casein rather than the albumin and globulin which controls the surface activity of milk. The surface activity of protein-free milk is due to a proteose. *See* Detergents; Foaming.

Refs.: Clayton; Rogers; Moulton (editor) (1943), *Surface Chemistry*, Washington; Adam.

SURFACE TO VOLUME RATIO. This decreases with increasing volume and is of great importance in relation to the contamination of milk by dirty utensils and containers. Contamination or non-sterility is usually measured in terms of bacteria per sq. ft., *e.g.* the suggested standard is 5000 for a satisfactorily " sterilised " piece of equipment. It follows that on this basis the larger the container the fewer the bacteria and so the less the contamination *per unit capacity*. The surface-volume ratios of milk containers are given in Table Su I.

TABLE Su I

RATIO OF INTERNAL SURFACE AREA TO VOLUME OF MILK BOTTLES, CHURNS, AND TANKERS

Container	*Capacity*	*Volume of milk (ml.)*	*Internal surface area (sq. cm.)*	$\frac{\text{Surface area}}{\text{volume}}$
Bottle . . .	⅓ pint	189	191	1·01
	½ pint	284	247	0·870
	1 pint	568	401	0·706
	1 quart	1136	601	0·529
Churn . .	10 gal.	44,500	7965	0·175
Tanker . .	1500 gal.	6,800,000	245,000	0·036
	3000 gal.	13,600,000	374,000	0·027

For a given surface contamination of the container, the contaminating effect of a ⅓ pint bottle is thus nearly 40 times that of a 3000 gal. tanker and 6 times that of a churn.

This is the reason why the smaller the volume the more important it is to attain sterility, as a container begins to affect the keeping quality of milk when its bacterial content is of the same order as that of the milk put into it. *See* Churns, dirty, effect on keeping quality.

SURPLUS MILK. Milk which is surplus to the day-to-day liquid requirements. Although milk production has increased steadily, the advent of the priority schemes has almost eliminated the problem.

See Milk marketing; Utilisation.

Ref.: Macneilage (1929), *Surplus Milk and Milk Residues*, Hannah Research Institute.

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[1] A force per unit length ($MLT^{-2} \div L$) is dimensionally equivalent to an energy, per unit area ($ML^2T^{-2} \div L^2$.

SURVIVAL OF MICRO-ORGANISMS. *See* Disinfection ; Stability ; Sterilisation ; Thermoduric bacteria ; Thermophilic bacteria.

SUSPENSION. Matter scattered throughout a liquid in the form of very small particles, but not so small as to form a sol. Suspended matter can be filtered off; a sol cannot be removed by ordinary filters.

Refs.: Ljung (1949), *IDC*, **4**, 667 ; Carlberg, 734.

SWEDEN. Swedish Dairies Assoc. (1946), *The Dairy Industry in Sweden*, Stockholm ; Ashton (1946), *DI*, **11**, 499.

SWEET. In dairying this term means non-acid or non-soured or non-ripened, and also free from taint. *See* Butter ; Cheese ; Flavours.

SWEET CREAM BUTTER. Butter made from cream in which no " ripening " or development of acidity has taken place. *See* Butter.

SWEET CURDLING IN MILK AND CREAM. Sweet curdling is one of the common bacteriological faults to which milk is subject. In bad cases the whole quantity of milk in the bottle or container becomes solid as though soured (although no acid has been produced) hence the term " sweet curdling ". In its early stages the fault appears in the cream layer at the top of the milk because the causative organism requires air for its growth. At this stage the fault may be called " broken cream " or " bittiness in cream ". The latter is a bad name, as it is easily confused with " bitterness in cream ", and its use should therefore be discontinued. The terms " incipient sweet curdling " or " curdy cream " are accurate and not likely to be confused with other faults.

In practice the fault is noticed when the cream floats in bits in tea or coffee (the " feathering of milk "). Two very simple tests to ascertain if the fault is present can be applied.

(1) Taste the faulty sample ; if sweet curdling is present either no taste at all or a slight bitterness will be detected. There is no trace of any sour or acid taste. This may be checked by titrating the milk or cream, when it will be found that the titratable acidity is about normal.

(ii) Streak a loopful of the cream layer from a freshly opened bottle on a milk agar plate and incubate at 37° C. for 1 to 2 days. It will usually be found that when sweet curdling is present a practically pure culture of an aerobic spore-former is obtained. This is easily recognisable by its spreading colonies and peculiar lead-white or creamy colour.

The cause of sweet curdling is nearly always due to the production of *rennin* by the growth of aerobic spore-forming bacilli (*Bacillus*) in the milk, especially at the top. Rennin, the active principle of rennet, is an enzyme capable of clotting milk without development of acid. Often an almost pure culture of organisms of the *B. mycoides* type is obtained. Colonies of this bacillus have a characteristic tree-like (arborescent or rhizoid) appearance on agar media. This is so peculiar to *B. mycoides* that in practice it serves to differentiate it from other types.

Lecithinase production by *B. cereus* and *B. mycoides*, which attacks the fat globule membrane and so destabilises the cream, is also a factor.

The most important factors influencing this fault are (i) high temperatures ; (ii) age of the milk ; (iii) pasteurisation.

High temperature. The fault is most common in hot summer weather for two reasons : (*a*) high temperatures favour the growth of the organisms and the activity of the bacterial rennin, and (*b*) sources of infection (dust, flies, hay, etc.) are more in evidence at this time. These factors are responsible for the fact that the flora of winter milk is different from summer milk for a given bacterial count. Summer milk may contain relatively more spores ready to germinate and proliferate after pasteurisation. Another factor of importance is that not only will *B. mycoides* grow faster and produce more rennin the higher the temperature, but the ability of rennin to curdle milk increases tremendously with rising temperature at 20° C. upwards.

Age of the milk. *B. mycoides* does not grow rapidly in milk at ordinary temperatures, and it is, in addition, restricted by the growth of other organisms, especially the acid-forming types. Consequently, under normal conditions of milk production and distribution, *B. mycoides* does not grow sufficiently to produce any detectable fault. When milk supplies have been suffering from this fault, it is invariably noticed that the trouble occurs in milk kept over for more than 24 hr. Assuming a heavy seeding of the milk with the causative organism on the farm, probably not much growth occurs *en route* to the creamery on account of the cooling and the bacteriostatic substances in the milk. Once taken from the cold store, a bottle of milk in hot weather soon attains a temperature permitting growth of *B. mycoides.* A period of 24 hr. at about 70° F. may not be sufficient to result in a detectable curdling, but 36 to 48 hr. frequently leads to curdling in the cream layer and the inevitable customer's complaint.

Pasteurisation. Pasteurisation has been criticised on the grounds that " pasteurised milk goes putrid instead of souring normally ". Whatever the effect of pasteurisation on the keeping quality of milk, there is no doubt that pasteurised milk may " go off " in a different way from raw milk, which practically always sours. The reason for this is that pasteurisation upsets the balance of flora in milk by killing all heat-sensitive types (including *Str. lactis*, the common milk-souring organism) and leaving the heat-resistant types. The latter are, on the whole, more of the proteolytic than the saccharolytic type, and so instead of the milk sugar being fermented to lactic acid, in pasteurised milk the surviving flora attacks the protein to produce unpleasant taints or in certain cases " sweet curdling ".

This is the reason why pasteurised milk is more prone to this fault than raw. Sweet curdling is thus one of the few bacteriological troubles in the dairy industry which cannot be lessened by pasteurisation. In fact, heating to this extent increases the likelihood of the fault developing.

Combating Sweet Curdling. High temperatures, certain sources of infection which are very common in summer, pasteurisation and ageing of the milk, are predisposing factors for sweet curdling. The following steps may be taken to prevent the fault.

Temperature. (i) Cool the milk on the farm ; (ii) cool to 40° after pasteurisation and hold in the cold store at the dairy as long as possible ; (iii) during delivery protect the crates from the sun. The universal use of refrigerators in households would see the end of this, as of all similar food troubles, but customers usually resent being told to buy refrigerators to keep their milk sweet, holding the view that poor keeping quality is the dairyman's fault.

Sources of contamination and appropriate remedies. Probably the most important are flies, dust, soil, hay, etc., on the farm and also improperly cleaned and sterilised churns and bottles. (i) Ask farmers not to turn over bedding or distribute fodder during the hour immediately before milking ; (ii) protect receiving churns on the farm from dust by keeping a metal lid or cover on them ; (iii) keep flies out of the dairy ; (iv) see that all churns are thoroughly cleaned and sterilised (steaming for at least 3 min.) ; (v) see that bottles are getting efficient treatment in the washing machine. Bacteriological control of cleaned churns and bottles should be a regular feature of the dairy routine. It is unlikely that a modern dairy would contain sources of *B. mycoides*, but ingress of dust, especially in agricultural districts, through windows in the building, may be a potential source of trouble which it is advisable to remove by keeping such windows closed while milk is actually running over coolers, etc. Wet surfaces naturally reduce the chance of contamination from such causes. Avoid any horizontal piping and steam all piping when not in use. Holding tanks should be thoroughly cleaned and sterilised by steaming for at least 1 hr. Wood and other non-metal materials in any plant are best avoided.

Pasteurisation. The statement that pasteurisation may increase the incidence of sweet curdling prompts the suggestion that, when this fault is prevalent, it may be advisable not to pasteurise. With mixed bulk milks in summer it is unfortunately too great a risk. Failure to pasteurise would almost certainly result in souring instead of " broken cream ".

Ageing the milk. Assuming evening and morning milk is collected, pasteurised, cooled, held over night in cold store and delivered the following day, it will be evident that some of the milk is 40 hr. old on delivery to the customer. If the milk stands for one further day in the customer's house, it is then about 70 hr. old, which is all that one must reasonably expect from a commercial milk. Nevertheless, when this type of fault is prevalent, retailers would obviously be wise to get the milk delivered to the customer with the minimum delay. Unfortunately, the whole system of production, transport, treatment, and distribution is so inter-organised that usually it is not possible to deliver milk of less age than the 40 hr. mentioned. Whenever possible, " holding over " of milk in the creamery or store should be avoided.

Other Methods. As already stated, holder pasteurisation appears to accelerate the fault, partly because it destroys other organisms which normally suppress *B. mycoides*, and also possibly because the heat treatment has a stimulating effect on the germination of spores, which may be the chief type of infection in hot dusty weather. The circumstances of this fault resemble in some ways those of the " carbolic taint " in sterilised milk, and those interested in the fundamentals of the problem may with profit study this (pp. 970 and 998).

Alteration in method of pasteurisation. A common error in the milk industry is to raise the temperature of pasteurisation when normal pasteurisation fails to prevent a fault. This usually fails because heat-resistant cells like the spores of *B. mycoides* may require several hours at 212° F. to kill them. Raising the pasteurising temperature may even still further increase the prevalence of the fault. A more logical method of approach is to lower the pasteurising temperature slightly in order to permit a greater survival of acid-forming inhibiting types. This method cannot be used, of course, if officially pasteurised milk is sold.

Addition of inhibitory organisms. Perhaps the neatest way of combating any biological fault is the introduction of an organism which attacks or inhibits the activity of the fault-producing organism. With insect plagues the method is well established. The fact that normally certain bacteria of the acid-forming types suppress *B. mycoides* suggests that a possible solution would lie in the inoculation of such organisms into the milk. Experiments by the writer have shown that it is in fact possible to delay the appearance of the fault by the inoculation of certain bacteria, particularly the lactic acid streptococci. The best results were obtained with a slow-growing lactic streptococcus, and this would be the only feasible one in practice, as normally active streptococci would naturally sour the milk. Thus, the method, although of interest, cannot be recommended in practice as even a slow-acid-producing streptococcus might at any time become normal, *i.e.* fast.

Apparent sweet curdling, *i.e.* clot-on-boiling at normal acidities, can be caused by leakage of brine ($CaCl_2$) into milk, the increased calcium content destabilising the milk. Precipitation of protein also occurs when colostrum and other abnormal milks (*see* " May troubles ") are heated. *See* Rennet ; Spores ; Sterilised milk ; Thermoduric bacteria ; Thermophilic bacteria.

Refs.: Garvie and Stone (195), *JDR*, **20**, 29; Rowlands (1953), *JSDT*, **6**, 173; Stone and Rowlands (1952), *JDR*, **19**, 51; Stone (1952), *JDR*, **19**, 302, 311.

SWEETENED CONDENSED. *See* Condensed milk.

SWITZERLAND.

Refs.: Kästli and Schoch (1953), *DSA*, **15**, 517; Zollikofer (1949), *IDC*, **4**, 687; Czerniewski (1945), *Collection and Control of Milk in the Region of Zurich and Winterthur*, Zurich.

SYMBIOSIS. This term implies a " living together " of two or more organisms. In the strict sense neither organism can live or function without the other but the term is used loosely sometimes to imply mutual benefit. The interaction of organisms is better expressed by the term *association.*

SYNTHETIC CREAM. A cream-like material made by the emulsification of non-milk fats or hardened oils such as whale, ground nut, etc., formerly with dried egg, lecithin, soya, gelatine, etc., and now usually with carboxymethylcellulose, glyceryl monostearate, etc. Care must be taken not to confuse this with Artificial cream (p. 57). Modern synthetic or imitation cream is made from vegetable fats, sugar, water and such stabilisers as methylethylcellulose. It may contain no protein or nitrogenous matter and so is more resistant to bacterial growth.

T

TABLES. *See* Thermometric scales; Weights and measures.

TACHOMETER. An instrument for measuring the speed of rotation.

"TACKLE." A colloquial term for udder.

TAETTE MILK. A ropy fermented milk in Scandinavia consisting of a culture of a slime-forming variant of *Str. lactis*. *See* Ropy milk.

TAINTS. *See* Clean milk production; Flavours; Stability, microbiological.

TALLOWINESS. A taint in butter, milk powder, and other dairy products caused by oxidation of unsaturated fatty acids, catalysed by copper, light, and other factors. *See* Anti-oxidants; Auto-oxidation; Flavours; Milk powder; Rancidity.

TANKERS. Tankers consist of cylindrical tanks of up to 3000 gal. capacity made of stainless steel, " glass-lined " steel or aluminium and mounted on rail or road chassis (*see* Transport). The normal fittings are a manhole to allow operatives to enter the tank for cleaning purposes, a cock at one or both ends and valves to allow the ingress or egress of air. Tankers may be emptied by pumping (p. 860) or by blowing in compressed air. Filling is usually effected by a pipe or hose through the manhole and this should allow the milk to fall as gently as possible against the side of the tanker; excessive splashing can lead to frothing and aeration which will affect the solids-not-fat value due to a decrease in gravity. Values up to 0·15 per cent. below the true value can be obtained.

Tankers are normally insulated by 2 or 4 in. of cork or other material over all or part of their surface. Large bulks of chilled milk suffer little rise in temperature; usually this rises 1° to 2° in filling and 1° to 2° F. in transit.

Tankers must be filled as otherwise churning may take place; road tankers usually consist of two compartments. *See* Cleaning and sterilising; Cooling; Refrigeration; Surface to volume ratio.

Refs.: Matthews (1945), *DI*, **10**, 479 (construction); Inglis, *ibid.*, p. 483 (economics); Burgess, *ibid.*, p. 491 (bacteriological aspects).

TECHNICAL CONTROL OF DAIRY PRODUCTS. The term control includes not only laboratory tests but also control by instruments and other devices in the factory. The latter are steadily increasing as they give quick results and do not require highly-trained staff. *See* Bacteriological grading; Butter; Cheese; Condensed milk; Fat; Laboratories; Milk powder; Routine tests; Sampling; Solids-not-fat; Testing of milk supplies.

Refs.: *Milk testing; LCDP;* Cuttell; Hill; Richmond; Mojonnier and Troy (1922), *The Technical Control of Dairy Products*, Chicago.

TECHNIQUES. *See* Classification; Fat, determination; Freezing-point; Methylene blue; Phosphatase; Resazurin tests; Solids-not-fat; Total solids.

Refs.: *A.O.A.C.*; Chalmers; Cunningham; Eyre; Ling; Richmond; *S.M.D.P.*, Wright; Soc. Amer. Bact. (1936), *Manual of Methods for the Pure Culture Study of Bacteria*, Geneva, N.Y.; Hunwicke (1931), *Essentials of Bacteriological Technique*, London; Med. Res. Counc. (1929), " A System of Bacteriology in Relation to Medicine ", H.M.S.O. (9 Vols.).

TECHNOLOGY. The study of scientific knowledge applied to industrial processes.

TEMPERATURE. *See* Heat; Instrumentation; Thermometric scales.

Ref.: Griffiths (1947), *Methods of Measuring Temperature*, London.

TEMPERATURE COMPENSATED TESTS. *See* Bacteriological grading.

TEN-MINUTE RESAZURIN TEST. The official platform test under the National Milk Testing and Advisory Scheme for milks suspected to be souring. Milks giving a disc number of 6 to 4 are accepted, 3½ to 1 rejected. The same standards have now been adopted in the Joint Milk Quality Control Scheme.

See Bacteriological grading; National Milk Testing Scheme; Platform testing; Resazurin tests; Routine tests; Testing of milk supplies.

TENSION. The condition of a body acted on by forces operating in opposite directions, *i.e.* away from each other. Such forces are themselves sometimes called tensions. The opposite of " compression ".

TESTING OF MILK SUPPLIES.[1] In this country about 1600 million gal. of milk are produced annually and sold to creameries, food manufacturers, and the public. The constantly varying and perishable nature of milk makes its examination in the commercial laboratory a matter of considerable importance. Probably no other product is so intricate and uncertain in its properties and behaviour

TABLE Te I

Property	*Test*	*Factors controlling*
Subjective :		
" Richness " (popular)	Cream line	Fat content, globule size (breed of cow)
Colour	—	Carotene content—breed of cow
Smell Taste } Flavour	—	Bacterial content ; nature of feeds ; mastitis
Sediment (visible dirt)	Pad sediment test	Carelessness in milking ; filtering on the farm
Physical :		
Sourness	*p*H determination	Bacterial fermentation ; mastitis
Clotting with rennet	Rennet test	*p*H and protein constitution (mastitis)
Chemical :		
Acidity (alkali neutralising capacity)	Titratable acidity	Solids-not-fat content ; initial *p*H ; mastitis ; developed lactic acid
Fat	Gerber and Babcock (Röse-Gottlieb)	Breed of cow ; morning or evening milking ; skimming the milk ; watering
Solids-not-fat	Calculation from density	Mastitis ; breed of cow ; watering
Total solids	Drying at 100° C.	—
Added water	Freezing-point	--
Protein constitution	(i) Gold sol (ii) Casein number	Mastitis
Total protein	Formol titration	—
Bacteriological :		
Bacterial content	(i) Plate-count (ii) Direct microscopic count (iii) Methylene blue (iv) Resazurin (v) Presumptive coli	Carelessness in milking and handling ; mastitis ; warm weather ; dirty utensils
Physiological :		
Cell content	(i) Cell count (ii) Catalase (iii) Centrifuge deposit (iv) Resazurin	Mastitis ; stage of lactation ; mechanical injury to udder

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[1] For a brief survey *see* " Routine tests ".

as milk. While those concerned with the sale of liquid milk to the public are interested mainly in the public health and keeping quality aspects (*i.e.* bacteriological control), the food manufacturer has to take into consideration also the chemical, physical, and physiological properties of the milk he purchases. Table Te I summarises these properties and the tests discussed in this article. Only the simple routine methods are considered, as the more accurate and time-consuming tests (mentioned in brackets in the table) are not worth doing commercially except for special reasons. The usual routine tests may be divided into two classes: (i) those for the routine grading of supplies, and (ii) those for picking out the " bad " milks on the receiving platform. The latter must be instantaneous or at least very rapid. For routine grading it is better to apply a simple test which is reasonably accurate a number of times than to make one or two very accurate determinations, because of the inherent variability of milk. These accurate tests, notably the Röse-Gottlieb method for fat, the gravimetric method for solids-not-fat, and the freezing-point test for added water, are only used when the simpler tests have pointed to gross deficiencies and legal action or warning is contemplated.

Although considered under various headings, some of the chemical and bacteriological properties are interrelated.

It will be observed that mastitis can affect all five major aspects of milk : yield, fat, solids-not-fat, flavour, and keeping quality.

Subjective Tests. (i) ***Cream line.*** This is probably the oldest and, in the popular view, the most important test used for milk. Many housewives will judge the quality of their supply on this alone and ignore the keeping-quality aspects.

The cream line is, of course, not a reliable guide to the " richness " or fat content. Temperature and the size of the fat globule appreciably affect the cream line for a given fat content ; low temperatures, although slowing up the rising of the fat globules, result in a deeper cream layer, and the milk from the Channel Islands breeds containing large globules exhibits a deeper cream line than that from other breeds, such as Shorthorn and Ayrshire. The rich colour of the Jersey and Guernsey milk also enhances the cream line effect.

(ii) ***Colour.*** While admitting that the yellow creamy colour of Channel Islands milk is pleasing and has a definite commercial value, it must not be forgotten that a rich colour does not necessarily mean that the fat-soluble vitamin content is greater than in a paler milk. A deficiency in carotene may be compensated by a higher vitamin A content, the vitamin itself being colourless.

(iii) ***Smell.*** This is the standard test applied at creameries and factories. The nose can often detect taints when all other tests fail. It is therefore a very delicate test, especially when the lid is first taken off the churn. A few comments on this point may be of interest.

(1) When churns arrive at the receiving platform the lids are removed and the milk in the churn smelled or, in some cases, the churn lid is smelled. It follows, therefore, that not only the milk but the churn *and lid* are included in the test. Most buyers now clean and sterilise their churns very efficiently but it must be admitted that there are places where this treatment is not carried out properly for various reasons (*e.g.* too weak a detergent, running the washing machine before the temperature of the detergent is up, etc.), and it should be made an offence for any purchaser to return improperly washed and sterilised churns to producers.

(2) In summer a tainted milk probably means a dirty milk, but in winter, when bacterial growth is slow, other taints such as those due to feeds, enzymes, catalysts, etc., may form an appreciable proportion of the total. It is unjust to condemn such milks as dirty for two reasons : (i) the taint is not due to faulty methods of production in the ordinary sense, and (ii) the milk, although perhaps having an unpleasant smell in the churn, will not usually affect adversely the keeping quality of the rest of the milk, and the odour will in all probability pass off on standing or aeration.

Taste. Milks are usually not tasted in routine testing. Nevertheless certain taints, such as bitterness, will escape detection by smell alone. In keeping-quality tests milks should be first smelled at a temperature of 35° to 40° C., and then heated to 72° to 75° C. to destroy any undesirable organisms before tasting. Boiling, however, produces a cooked flavour which may mask others.

Sediment. Visible dirt in milk may be classified as (i) sand, gravel, etc.; (ii) soil; (iii) dung; (iv) hair, etc.; (v) pus, etc. Of these (i) is of little consequence, but (ii), (iii), (iv), and (v) are very undesirable. It may be mentioned, however, that the effect of dung on milk is less than that attributed by popular sentiment. Its effect is far less, for example, than that of milk residues in dirty utensils. In fact, although the presence of coliform organisms is commonly attributed to faecal contamination, dirty utensils are, in practice, the most important source of these bacteria and the most frequent cause of poor keeping quality. Coliform organisms proliferate rapidly in milk and milk wastes, especially in warm weather, and are a common cause of poor keeping quality.

There is little correlation between sediment and keeping quality or any of the bacteriological tests, at any rate in winter. Producers are, of course, supposed to filter their milk on the farm, but many do not, and some of those who do filter are, in fact, contaminating the milk by using unsterile filter cloths. Pus and cell debris are aesthetically undesirable and abnormal amounts indicate mastitis. Sometimes churned fat may stick on the sediment pad and simulate pus, but this is readily detected on drying the pad.

Sourness. The commonest fault in milk, at any rate in summer, is souring, due to the growth of lactic streptococci, coli-aerogenes bacteria and, to a lesser degree, other lactose-fermenting organisms such as staphylococci. Fresh normal bulk milk has initially a *p*H of 6·5 to 6·65, a higher *p*H indicating mastitis and a lower one souring. Milk begins to clot at pasteurisation temperatures (145° to 160° F., or 63° to 70° C.), when the *p*H is about 5·7 and the titratable acidity about 0·32 per cent., although deposits are formed at much lower acidities, so that the practical limit for pasteurisation is about 0·22 per cent.

When boiled, milk will clot at about *p*H 6·0, titratable acidity about 0·24 per cent. At room temperature (18° C.) milk clots at *p*H about 5·1, titratable acidity about 0·6 per cent. For a given salt balance and protein constitution the *p*H and not the titratable acidity is the real criterion of the degree of souring and whether milk will pasteurise without clotting. Two groups of tests are available for testing the *p*H of milk—accurate electrometric methods and approximate indicator methods.

Electrometric Methods. The glass electrode is, of course, the best method, but its expense prevents its general adoption. Care should be taken when testing milks to clean the electrode thoroughly between tests, as otherwise adsorbed films of protein and fat may lead to serious errors. The electrode should be cleaned in *dilute* acid or alkali. Greasy films may be removed by carbon tetrachloride; solvents such as acetone should be avoided, as these dehydrate the glass surface and lead to unstable potentials.

The quinhydrone method is simple and convenient under normal conditions, although large numbers of sulphide-producing bacteria may lead to poisoning of the electrode. If a potentiometer is available the apparatus is not expensive, and a very simple outfit is satisfactory for routine work. It is convenient to use $\frac{M}{20}$ phthalate buffer for the standard half-cell instead of the usual hydrochloric acid-potassium chloride "buffer", and to use a standard phosphate buffer at *p*H 6·81 for checking the electrode. With care the error does not exceed ± 0·02 *p*H units — the error of the standardising buffer (p. 675).

Indicator Methods. The turbidity of milk prevents the direct determination of the *p*H in a comparator. Sharp and McInerney have described a dilution method to overcome this difficulty, and Davis and Thiel (1940, *JDR*, **11**, 71) have suggested that bromthymol blue is preferable to phenol red for routine work, as, although it behaves abnormally, better matching is obtained. The average error is about 0·05 and only occasionally greater than 0·15.

Various indicator-impregnated cellophane slips are available on the market, but as their error is at least ± 0·1 they are hardly worth the time involved in use and expense in purchase.

A well-established test is the alcohol-alizarin test, in which both the colour of the indicator and the degree of precipitation of the protein serve to indicate the lowering of *p*H. The variable fat content and pigment of milk seriously influence the indicator part of the test. To make the test at all accurate, therefore, it is essential to have separate standards for Channel Islands milks.

Clotting with Rennet. The rennet test is the simplest test for the normality of milk. Clotting is accelerated by low *p*H values (*i.e.* souring) and the presence of milk from freshly calved cows. It is retarded by high *p*H values, low casein and calcium, and abnormal protein constitution. All three conditions are caused by mastitis, and in practice it may be assumed that milks clotting slowly with rennet are from infected cows.

The rennet test is conveniently combined with the resazurin test, as these two tests work independently of each other. It is advisable to standardise the age of the milk in the rennet test, *e.g.* single cow samples at 3 hr. after milking and bulk milks (evening and morning mixed) at about midday.

Chemical Tests. ***Titratable acidity.*** When only one " scientific test " was made on milks in creameries and factories, this was commonly used. There was a tacit assumption that fresh milk has an acidity of *c.* 0·14 per cent. lactic acid, and that if the acidity exceeded this it was due to souring. The usual plan was to reject milk if it had a taint by smell and the acidity was over a certain limit, usually 0·2 per cent. in summer and often less in winter, *e.g.* 0·17 per cent. The writer has known a limit of 0·15 per cent. set in winter. It is unfortunate that the nature of the acidity of milk is quite unrealised by most of those making the test, both in the dairy and other industries. As used in practice, the test may lead to gross injustice to the producer, especially in winter. Generally speaking, it may be said that titratable acidity (T.A.) measures not only souring but also the protein and phosphate in the milk. In fresh milk, or milk in which only a negligible degree of souring has taken place, there is no correlation between bacterial content or keeping quality and T.A. but a good correlation between solids-not-fat and T.A. It follows, therefore, that rich milk high in solids-not-fat, will give a high T.A., and " mastitis milk " low in solids-not-fat a low T.A. Hence it is possible for a rich milk of low bacterial content to give a high T.A., and if it has a slight odour, which may be due to feed or other quite harmless causes, it may be condemned. On the other hand, " mastitis milk ", being of low T.A., is regarded as good milk. In summer the T.A. test is reasonably safe in the hands of the control laboratory ; in winter, when souring is slight, it is not only useless but misleading. Thus the writer has known of some milks which had an *initial* T.A. of 0·22 per cent. and which were returned to the producer for this reason, to his eternal perplexity. The general adoption of the ten-minute resazurin test (*see* Platform testing) has now eliminated some anomalies.

Table Te II summarises the usual effect of souring, watering, and mastitis on the *p*H, titratable acidity, formol titration, and their ratios.

The resultant values are, of course, not rigid and will vary according to the degree of abnormality, souring, and watering. They do show, however, that the factors can mask one another in these simple tests. For example, it is impossible, using only the *p*H, titratable acidity, and formol titration tests, to distinguish normal unsoured milk from soured mastitis milk. This is a good example of the inherent unsoundness of the titratable acidity test. From the point of view of effect on the keeping quality of a bulk of milk, there is a considerable difference between an unsound normal milk and a slightly soured mastitis milk, as the latter, although indistinguishable from the former at the time of testing, will seed the bulk with a number of souring organisms.

Fat estimation. This is the compositional aspect most commonly estimated and there are many reasons for this. It is the only constituent which can be visibly detected (cream line), it defines the butter yield of milk and very largely the cheese yield. In England the legal limit for fat is 3 per cent. This is a generous one, but in the flush period of summer some producers have difficulty in this direction, especially in the morning milk of the low fat breeds (Friesian and to a less extent Shorthorns). The Gerber test is almost universally used in this country and has an accuracy of ± 0·05 to 0·1 per cent. If a low value is obtained and legal action is contemplated, a gravimetric determination such as the Röse-Gottlieb or Adams should be made. Before the war it was not uncommon for creameries to pay a bonus for butterfat when butter or cheese was made.

Solids-not-fat. Although comparatively ignored, this is of more importance from a nutritional point of view than the fat. Whereas the latter is important in itself and also as a source of vitamin A (the amount of D is very small), the former contains first-class protein, sugar, calcium, and other salts, and the B vitamins, especially B_2. The legal limit is 8·5 per cent., and it is probable that failure to attain this is due to inefficient breeding, seasonal or feeding effects in late winter and late summer, and to mastitis.

TABLE Te II

Milk	*Souring*	*Watering*	*pH*	*T.A.*	$\frac{pH}{T.A.}$	*Formol titration*	$\frac{T.A.}{\text{Formol titration}}$
1 normal .	0	0	N	N	N	N	N
2 normal . .	+	0	low	high	low	N	high
3 normal . .	0	+	N	low	high	low	N
4 normal . .	+	+	low	N	low	low	high
5 abnormal .	0	0	high	low	high	N	low
6 abnormal .	+	0	N	N	N	N	N
7 abnormal .	0	+	high	low	high	low	N
8 abnormal .	+	+	N	N	N	low	high

N = Normal.

The invariable routine method is to determine the density by a hydrometer and then to calculate the solids-not-fat from the fat and density. A more accurate form of the old Droop Richmond formula T.S. $= \frac{6}{5}F + \frac{G}{4} + 0{\cdot}14$ is now available, *viz.*, T.S. $= 0{\cdot}25D + 1{\cdot}21F + 0{\cdot}66$. *See* Solids-not-fat.

The error does not usually exceed ± 0·1 per cent.

The value of solids-not-fat figures for the buyer is twofold : (i) it helps him to safeguard himself against possible legal action for selling milk below the legal limit, and (ii) it affords a valuable clue to advisory work on mastitis.

Total solids. This is, of course, the sum of the fat and solids-not-fat. The nutritive value and also, generally speaking, the value of milk for food manufacturing purposes and cheesemaking are dependent on the total solids in the milk. Moreover, the cost of production of milk is directly dependent on its total solids content. It is only just, therefore, that milk should be bought on a total solids basis. Broadly speaking, high fat goes with high total solids, but where milk is required specifically for cream or buttermaking a special fat bonus may be paid. Milk *may* be high in fat and low in solids-not-fat, and *vice versa*. The first condition is generally due to mastitis, especially in a Channel Islands herd, and the second to failure to mix properly, skimming or holding back the strippings.

A direct determination of total solids may be made by drying milk for 3 hours at 100° C. or by the rapid Carter-Simon oven method. If the solids-not-fat value is also required, the fat must be determined as well.

Added water. There is little doubt that some samples of milk contain added water, and this fraudulent practice is not always hunted down and the perpetrators punished as they should be. However, adulteration may be unintentional, *e.g.* *via* a leaking cooler. Payment on a total solids basis would abolish the evil as far as the producer is concerned (p. 866).

The best method of detecting the presence of added water is undoubtedly the freezing-point. This depends on the fact that milk always maintains a practically constant osmotic pressure corresponding to a freezing-point of about − 0·544° C. Mastitis lowers the lactose and raises the sodium chloride content, the osmotic pressure remaining constant. Although accused producers defend themselves by assertions of illness in the cows, unusual feeding methods, etc., there is no evidence that any of these can affect the freezing-point significantly. For recent investigations *see* Freezing point. Extremely rare cases of individual cows giving milk of abnormal freezing-point have been reported, but the producer is always safeguarded by the " appeal to the cow " test (p. 56).

Another test depends on the fact that all naturally occurring water contains nitrate, but this has not been extensively used in this country.

A low fat *and* solids-not-fat suggests the addition of water ; a low solids-not-fat and only slightly low or normal fat, mastitis.

An apparatus permitting the rapid determination of the freezing-point has been described by Temple (1937), *A*, **62**, 709.

Protein. Normal milk contains about 78 per cent. of its total nitrogen as casein, 10 to 14 per cent. as albumin, 4 to 6 per cent. as " globulin ", and 5 to 6 per cent. as non-protein nitrogen. The last is fairly constant, but the ratio of casein to the water-soluble proteins is variable and appreciably affected by mastitis.

Aschaffenburg (1939, *Nature*, **143**, 523), has applied the gold sol test to milk and shown that it can be used as a simple test for abnormal milks. It thus resembles the rennet test, with the important difference that the gold sol test is independent of the *p*H of the milk, whereas the rennet test is greatly affected by the *p*H and therefore by souring. For a given abnormality in protein constitution the rennet test will be the more sensitive the higher the *p*H, the gold sol test remaining at the same sensitivity.

The Kjeldahl method is usually employed when an accurate value is required ; an approximate figure may be quickly obtained by using the formol titration method. This may be considered as a simple empirical estimation of the protein in the milk. A fairly accurate idea of the casein content may be obtained if this is first precipitated and filtered off before titrating. As ordinary mastitis does not significantly affect the total protein content of the milk, " mastitis milks " usually have a normal formol titration and a low T.A. The casein proportion is low, and this fact can be used as a chemical method for diagnosing mastitis with, however, the usual limitation in that late lactation milk physiologically resembles mastitis milk. The determination of total and casein nitrogen by the formol titration is not sufficiently accurate for this purpose, although the worst cases can be detected by this simple modification of the casein number technique.

Bacteriological Examination. There is no really accurate method for determining the bacterial content of milk and milk products. Many methods are available, some of them indirect, and each has its own characteristic limitations and advantages. As from the industrial point of view keeping quality and flavour are the most important aspects, it is advantageous to use methods which either distinguish those types of flora particularly affecting these properties or are considerably affected by the organisms concerned.

The following methods are available for purposes of routine examination : *Direct.*—(i) Direct microscopic count. (ii) Plate colony count. *Indirect.*—(iii) Methylene blue test. (iv) Resazurin test. (v) Presumptive coliform test.

Sediment Test. This is a method of estimating visible dirt in milk. A given quantity of milk (usually ½- or ⅛-pint) is forced through a fine filter pad and the deposit of dirt estimated by comparison with standards. Careless methods of production and handling usually result in heavy contamination with bacteria, a high plate-count, a short methylene blue reduction time, and a bad sediment test. *See* Abnormal milk; Bacteriological grading; Coliforms; Fat; Mastitis; Methylene blue; Microscopic count; National Milk Testing Scheme; Plate count; Quality payment; Resazurin tests; Routine tests; Solids-not-fat.

Refs.: Chalmers; Richmond; Wilson *et al*; *Milk Testing;* Whitehead and Sargent (1951), *Milk Testing for Milk Plant Technicians;* B.S. 1741 (1951) (chemical); Davis and Ashton (1951), *JSDT*, **4**, 78.

TETRACOCCUS. (i) A general term applied to any coccus whose cells form clusters of fours. (ii) Also used formerly as the name of a genus.

TETRADECENOIC ACID. An unsaturated fatty acid 5 : 6 $C_{13}H_{25}$. COOH occurring in small quantities in milk fat. *See* Fatty acids.

THALLOPHYTES. A class of primitive, rootless, stemless plants including bacteria, yeasts, and moulds. *See* Classification; Moulds.

THEELIN. Oestrin. *See* Hormones; Milk secretion.

THERMAL CAPACITY. *See* Specific heat.

THERMAL CONDUCTIVITY. Scientifically this is measured by the amount of heat transferred in 1 sec. between two opposite faces of a cube of 1 cm. maintained at a constant difference of 1° C. (calories).

In engineering the heat transfer across a cube of 1 ft. with a temperature difference of 1° F. (B.Th.U.). In practice the *overall coefficient* which includes the " film effect " is used.

Refs.: Badger and McCabe; Farrall.

THERMAL DEATH POINT. That temperature at which all or a certain proportion, *e.g.* 99·9 per cent. of bacteria in a culture, are killed in a certain time *e.g.* 10 min. *See* Pasteurisation; Thermoduric bacteria.

THERMAL EFFICIENCY. The ratio of heat utilised by an engine to that contained in the fuel consumed.

THERMAL EXPANSION. Most materials expand when heated and allowance must always be made for this when designing and operating plant.

TABLE TE I

Material	*Coefficient of linear expansion per ° F.*	*Material*	*Coefficient of linear expansion per ° F.*
Cast aluminium	0·0000123	Tin	0·0000115
Rolled aluminium	0·0000115	Zinc	0·0000160
Brass	0·0000105	Brick	0·0000031
Copper	0·0000095	Fire brick	0·0000027
Cast iron	0·0000060	Building stone	0·0000040
Wrought iron	0·0000065		to
Lead	0·0000158		0·0000080
Nickel	0·0000070	Glass	0·0000049
Steel (untempered)	0·0000060	Porcelain	0·0000020
Steel (tempered)	0·0000070	Slate	0·0000058

THERMODURIC BACTERIA. The phenomenon of heat resistance among certain genera of bacteria is of great practical importance in dairying and other food industries. The high degree of heat resistance shown by spore-forming organisms of the genera *Bacillus* and *Clostridium* was among the first discoveries of the early bacteriologists, *e.g.* Koch (1881). Later work, by dairy bacteriologists in particular, has shown that among a number of so-called vegetative species, heat resistance higher than that normally associated with vegetative forms can be found.

The term " thermal death point " of an organism is a function of time and temperature, and is affected by a number of factors, *viz.* age of the culture, temperature of incubation, nature of medium, hydrogen-ion concentration, previous history of the organisms, and the actual numbers present in the heated material. There is no universally recognised standard method of determining the thermal death point of an organism. As a rule, investigators have studied the problem from the practical aspect of their particular field of bacteriology and accordingly different methods and standards have been followed. Mattick and Hiscox (1945, *SAB*, p. 78) in a study of heat resistance and related problems suggest that the older methods of plating as proof of heat destruction are unreliable as small numbers of survivors may be missed and the quantity examined is too small. In their view cultures should be included in liquid, or for some species, semi-solid media and the medium employed should be complete, *i.e.* capable of supplying all the growth requirements of the organism.

It is generally agreed that heat destruction of bacteria is due to protein coagulation; the higher the temperature the quicker is the cellular protein coagulated (Wilson and Miles). For vegetative forms it is found that exposure to a temperature of 60° C. for 15 to 20 min., as a rule, is fatal (Mattick and Hiscox), but spores can withstand a temperature of 80° C. for 20 min. The resistance of the spore is thought to be due to the greater percentage of " bound " as opposed to " free " moisture in the spore.

Between the vegetative non-heat resistant species and the spore-forming heat-resistant species a number of bacterial types with an intermediate degree of heat resistance are to be found. In dairy bacteriology it is this intermediate group which is denoted by the term " thermoduric ".

Thermoduric forms have been found among the following genera : *Micrococcus* and *Sarcina*, *Streptococcus*, *Corynebacterium* (*Microbacterium*, Orla-Jensen), *Escherichia* and *Aerobacter*. The importance of such organisms was first appreciated both in this country and abroad, particularly in the U.S.A. and Canada, when numerical standards were applied by health authorities to heat-treated milk. For early work in America, reference may be made to Breed (*N.Y. State Agric. Exp. Sta. Bull.*, 1928, 599), and Robertson (1927, *N.Y. State Agric. Exp. Sta. Bulls.*, 130 and 131). The first work in Britain was that of Anderson and Meanwell (1933), *JDR*, **4**, 213 ; (1936), **7**, 182.

Micrococcus and Sarcina. The micrococci, along with sarcina, are common udder and skin commensals. It is debatable whether the udder is the source of these heat-resistant species. Abd-el-Malek (1943, *SAB*, p. 23), was unable to isolate them from aseptically-drawn milk and Mallman and Bryan (1943, *Ass. Bull. int. Ass. Milk Dlrs.*, **35**, 175), only isolated thermoduric species in 6 udder samples from 102 cows. The heat-resistant species most frequently encountered by Robertson was *Sarcina lutea*, which formed a luxuriant bright yellow growth on agar. Other types isolated by this worker were *Sarcina rosea* and *Micrococcus conglomeratus*. A heat-resistant micrococcus resembling *M. viscosus* (Bergey), capable of producing ropiness in pasteurised milk has been described by Murray (1946, *SAB*, **2**, 91). This contaminant was found in flooded pastures and water supplies.

Streptococcus. Three species of heat-resistant streptococci may be found, *viz. S. faecalis*, *S. durans*, and *S. thermophilus*. The two former belong to Lancefield's Group D and an adequate description may be found in a paper by Shattock (1945, *SAB*, 18). It is probable that *S. thermophilus* should be regarded as a thermoduric rather than a thermophilic species as the optimum growth temperature is approximately 45° C. The differential characters of the heat-resistant and non-heat-resistant streptococci commonly encountered in milk and milk products are set out in Table Th I. Minute colony formation is typical of many of the thermoduric streptococci.

Corynebacterium (Microbacterium, Orla-Jensen). From several standpoints this group constitutes the most interesting thermoduric bacterial genus found in milk. The taxonomy of the group is still a matter for debate. It is agreed that morphologically they are typical diphtheroids and as such should be placed in the corynebacteria, Jensen (1934, *Proc. Lin. Soc. N.S.W.*, **59**, 1-2); on the other hand, their marked heat-resistance and certain growth characters differentiate them from the commensal skin diphtheroids and also the corynebacteria of the soil, Orla Jensen (1919, *The Lactic Acid Bacteria*, Copenhagen). In milk these organisms have been found to have a high degree of heat-resistance, *e.g.* 85° C.

TABLE Th I

TYPING OF LACTIC STREPTOCOCCI

Species	*Lancefield's group*	*Haemolysis*	*Liquefaction of gelatin*	*Reduction of litmus milk*	*Growth in*			*Survive 60° C. 30 min.*	*Growth at*	
					Mannitol	*Sucrose*	*Raffinose*		*pH 9·6*	*45° C.*
S. faecalis . .	D	–	–	+	+	+	–	+	+	+
S. ,, *var. zymogenes*		+	+	+	+	+	–	+	+	+
S. ,, *var. liquefaciens*		–	+	+	+	+	–	+	+	+
S. durans . .		±	–	–	–	–	–	+	∓	±
S. bovis . .		–	–	–	∓	+	+	–	–	+
S. lactis	N	–	–	+	±	∓	–	–	–	–
S. cremoris . .		–	–	+	–	–	–	–	–	–
S. thermophilus .		–	–	–	–	+	–	+	–	+

	Growth at 40° C.	*Growth in*	
		4% NaCl	*Maltose*
S. lactis . .	+	+	+
S. cremoris .	–	–	–

Note.—*S. thermophilus* ferments only lactose and sucrose of the usual sugars. Maximum growth of laboratory cultures seldom takes place at 50° C. and usually fades out about 47·5° C. No growth in 2·0 per cent. NaCl.

for 10 min. and in some instances even 90° C. for 10 min. The reason for this resistance is not known. Bipolar granules are commonly found, even in young cells which, when stained, frequently resemble a diplococcus. They are Gram-positive but do not react with Neisser's stain. Microscopically they are frequently seen as small parallel bundles, due to a peculiar form of slip growth (*see* Figs. Th. 1, 2, 3 and 4). Branched forms are not common although seen occasionally. The natural habitat is doubtful and isolations have been described from the soil, bovine faeces, and milk. They are common contaminants on poorly sterilised milk equipment. On agar the organisms form small colonies in 3 to 4 days at 30° C. (37° C. is not a favourable growth temperature). The colony appearance cannot be used for differential purposes, creamy-white to lemon yellow colours with a soft or hard texture being found in various species indiscriminately. The principal reactions of *M. lacticum* and *M. flavum*, the types most commonly encountered, are shown in Table Th II. (McKenzie, Morrison and Lambert (1946), *SAB*, 37.)

Bacillus. Spore-forming rods of the genus *Bacillus* are common in raw milk, even in that produced under good hygienic conditions. The number present is rarely excessive (*see* Table Th III) and in milk pasteurised by either the Holder or H.T.-S.T. methods the vegetative thermodurics and post-pasteurisation contaminants generally predominate in the subsequent bacterial multiplication.

TABLE Th II

DIFFERENTIAL TESTS OF *M. lacticum* AND *M. flavum*

Species	*Litmus milk*	*Starch*	*Salicin*	*Lactose*	*Maltose*
M. lacticum .	Slightly acid in 5 days, no coagulation	+	+	+	+
M. flavum .	Negative or very slightly acid in 5 days	—	— (+)	+	+ —

TABLE Th III

TO SHOW THE RELATIVE PROPORTIONS OF SPORE-FORMING ORGANISMS IN BULK MILK. SAMPLES FROM 50 INDIVIDUAL FARMS

(Unpublished data, McKenzie and Lambert, Ministry of Agriculture, Leeds)

Total samples	*Colony count per ml. after heat-treatment at 80° C. for 30 min.*		
	< 100	100 to 200	> 200
50	25	16	9

In sterilised milk (p. 990), however, spore-forming rods are the sole survivors and are the usual causes of deterioration, *e.g.* sweet curdling, proteolysis, bitter and phenol flavours. A simple key to the identification of aerobic spore-forming bacilli has been drawn up by Gibson and Topping (1938), *SAB*, p. 43 (*see* Classification).

In warm weather these types are the common cause of the trouble known in the dairy industry as " bitty cream " due to the formation of either a complete or partial clot on the cream of pasteurised milk the clot being formed by the rennin-like and lecithinase enzymes of the organisms. *See* Sweet curdling.

Escherichia-Aerobacter (Coliform group). The existence of heat-resistant coliform types was strongly contested for some years. It now seems clear that the occurrence of thermoduric coliform organisms in farm milk supplies is rare ; only a few authentic cases may be cited. On the other hand, Crossley (1946, *JDR*, **14,** 233) has shown that 34·6 per cent. of coliform strains isolated from pasteurised milk could resist 63° C. for 30 min. in milk. He suggested that there may be a build up of a heat-resistant coliform type in imperfectly washed and sterilised dairy plant. The thermoduric strains belong principally to the *Escherichia* genus which is rather unusual as it might have been expected to find these mainly among the capsulated *Aerobacter* types.

The thermoduric genera are important in dairying for two reasons. First, because their presence in raw milk in appreciable numbers indicates unsatisfactory production methods and second, because their survival in pasteurised or heat-treated milk makes it difficult for the laboratory to measure the plant efficiency by colony count tests. On the other hand, it must be realised that they are non-pathogenic and their slow growth has no effect on the keeping quality of milk. The principal source of the organisms in raw milk is undoubtedly improperly cleaned and poorly sterilised farm dairy equipment, in particular the milking machine. For example, McKenzie and Morrison (1945, *SAB*, p. 26), found in a series of 35 farms with thermoduric counts exceeding 50,000 per ml., 34 milked by machine, which, in all these cases, was the principal source of contamination. The dairy churn may also be a prolific source of thermodurics particularly of those types multiplying readily at 30° C., but only in cases where the churn has not been satisfactorily cleaned and sterilised. For example, it has been shown that churns with a total count per churn < 100,000 have a negligible thermoduric content, whereas churns with counts > 1,000,000 per churn have, in most cases, a high thermoduric content. The distribution of thermoduric types from churns is illustrated in Table Th IV.

TABLE Th IV

DISTRIBUTION OF THERMODURIC TYPES FROM 72 CHURNS

(McKenzie, Morrison and Lambert (1946), *SAB*, 37)

Type	*No. of cultures*	%
Corynebacteria (microbacteria, Orla-Jensen)	498	73·1
Micrococci	67	10·2
Streptococci	18	2·7
Miscellaneous (including Gram-negative and filamentous rods	91	13·9
	654	

Thermoduric bacteria are regularly present in dried milk powder and may constitute approximately 50 per cent. of the total bacterial flora in the reconstituted milk. Higginbottom (1944, *JDR*, **13**, 308); (1945, *JDR*, **14**, 184), found that the bacterial flora of the roller-dried product consisted chiefly of micrococci, sarcinae and spore-forming bacilli, but the spray-dried product of *S. thermophilus* and *S. faecalis*. Hiscox (1945, *JDR*, **14**, 175), showed that plates of reconstituted dried milk incubated at 30° C. gave higher counts than those incubated at 37° C. due to the presence of micro-bacteria which grow poorly at the latter temperature.

Investigations from various centres in England and Wales suggest that the thermoduric content of milk in the South and West of England is lower than that in the North, Midlands, and Wales. It is possible, however, that the surveys so far reported from the former areas were confined to farms specialising in milk production and where a high degree of milking efficiency was to be expected, whereas the surveys from the latter areas included many small producers with limited equipment and facilities.

American investigators have suggested a seasonal fluctuation in the thermoduric numbers present in raw milk, with a peak towards autumn. The graph (Fig. Th 5), however, covering a year's survey for some 1400 producers to a North Yorkshire dairy does not show any marked seasonal fluctuation, nor does that of Table Th V from the work of Thomas *et al.* Moreover, in some further work in Lancashire in January and February, 1947, when the mean atmospheric temperatures were around freezing-point, McKenzie and Lambert found a high incidence of thermoduric organisms among 150 producers (*see* Table Th VI).

The usual method of estimating the thermoduric content of milk is by laboratory pasteurising an adequate portion of a well-mixed sample, say 10 ml., at 145° F. (62·8° C.) and cooling to 10° C. in water. The test-tube should be completely immersed during heat-treatment. Thereafter, dilutions of 1/10 to 1/1000 ml.

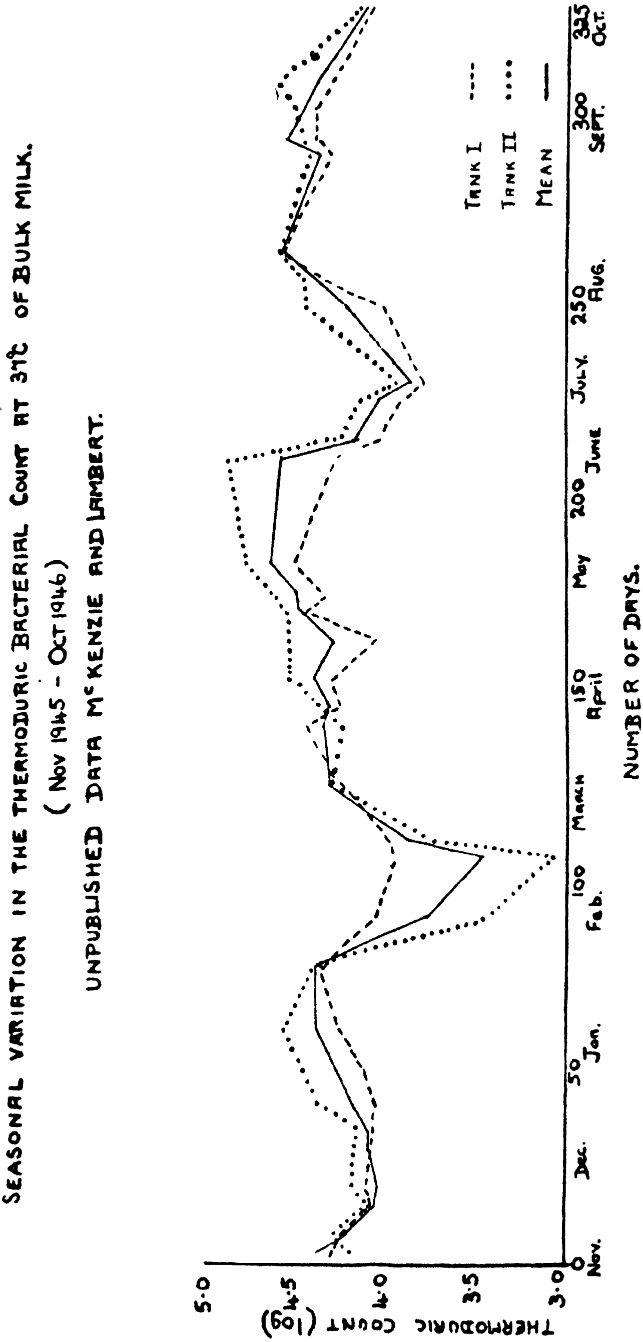

SEASONAL VARIATION IN THE THERMODURIC BACTERIAL COUNT AT 37°C OF BULK MILK.
(Nov 1945 - Oct 1946)
UNPUBLISHED DATA Mc KENZIE AND LAMBERT.
THERMODURIC COUNT (log)
5·0
4·5
4·0
3·5
3·0
0
Nov.
Dec.
50
Jan.
Feb.
100
March
150
April
May
200
June
July
250
Aug.
300
Sept.
325
Oct.
NUMBER OF DAYS.
TANK I ----
TANK II ····
MEAN ——

FIG. Th 5.

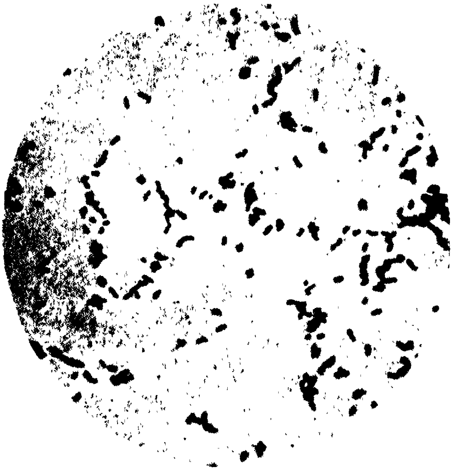


FIG. Th 1.—*Microphotograph of* 48-*hr. Culture of M. Flavum* (× 1000).

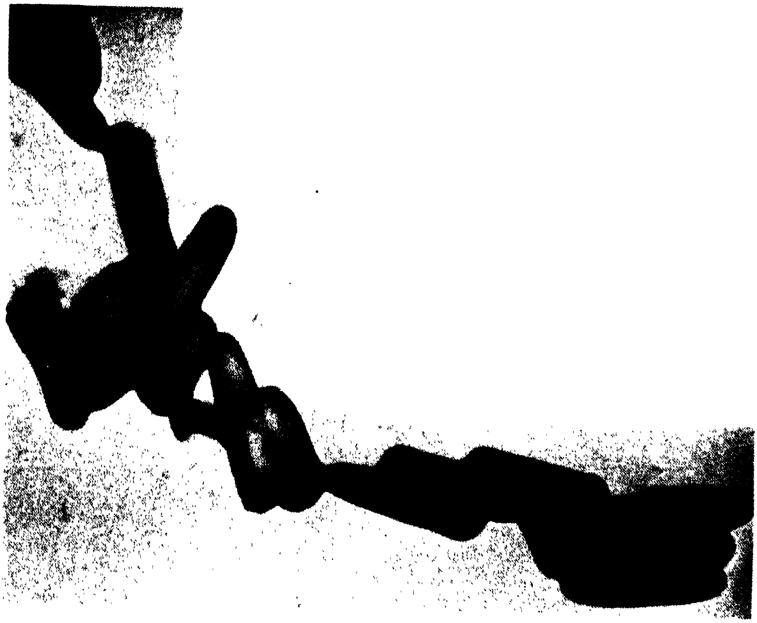


FIG. Th 2.—*Electron Microphotograph Illustrating Slip Growth of a Thermoduric Corynebacterium Species.*

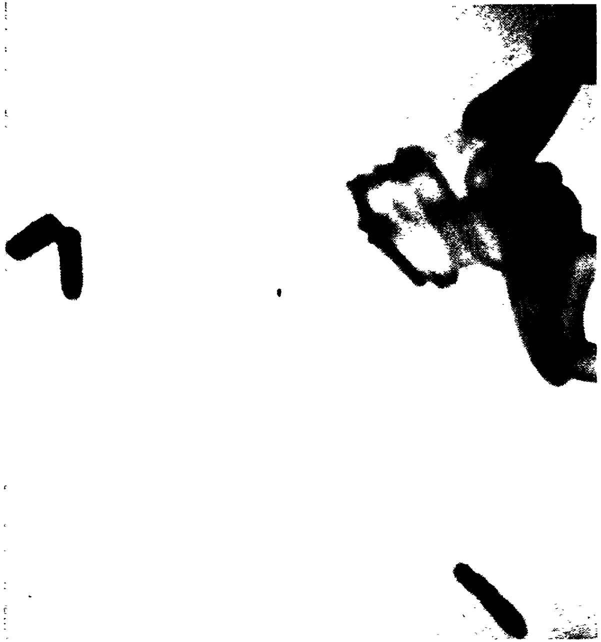


FIG. Th 3.—*Electron Microphotograph Showing " V " Formation of a Thermoduric Corynebacterium Species.*

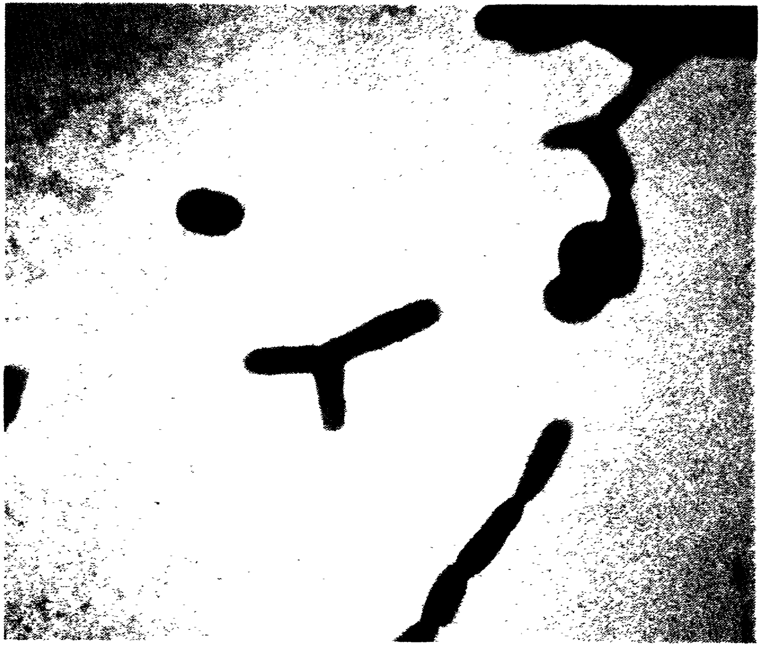


FIG. Th 4.—*Electron Microphotograph* (× 10,000) *Showing " Y " Branched Formation of a Thermoduric Corynebacterium Species.*

TABLE Th V—SEASONAL DISTRIBUTION OF THERMODURIC COLONY COUNTS

(Thomas *et al* (1947), *SAB*, No 1, 15)

Quarter	*Milk samples*	*% distribution of colony counts*				
		< 100	100 to 1000	1001 *to* 10,000	10,001 *to* 100,000	> 100,000
Dec to Feb	370	6 5	26 2	38 9	24 6	3 8
Mar to May	261	14 9	31 7	26 1	21 1	6 2
June to Aug	401	19 7	18 0	32 2	23 1	7 0
Sept to Nov	412	15 5	25 0	30 8	23 7	4 8
Totals	1444	14 3	24 6	32 4	23 3	5 4

TABLE Th VI—TO SHOW OCCURRENCE OF HIGH THERMODURIC COUNTS DURING WINTER, JAN TO FEB, 1947

McKenzie and Lambert (1947, *D*, **64**,10)

	Colony count per ml , 3 days, 30 C , 3 tests per farm				
No of farms	2000	2000 to 20,000	20 001 to 50 000	50,000	*Total tests*
150	203	128	32	95	458

TABLE Th VII—TO SHOW RELATIVE PROPORTIONS OF PRODUCERS GRADED ACCORDING TO KEEPING QUALITY STANDARDS AND PRODUCTION METHODS STANDARDS (LABORATORY PASTEURISED COUNT)

McKenzie and Lambert (1947, *D*, **64**, 10)

	%	%	*No of farms*	*No of farms holding designated licenses*
Percentage with				
Good K Q and good count	-	38 7	58	7
Good K Q and fair count	22 0	35 3	—	4
Fair K Q and good count	5 3		55	1
Fair K Q and fair count	8 0			1
Good K Q and bad count	13 3	17 3		7
Fair K Q and bad count	4 0		26	1
Bad K Q and good count	0		—	—
Bad K Q and fair count	2 0	2 0	3	0
Bad K Q and bad count	6 7	6 7	10	1

The following explanation of this table is necessary

A good resazurin record (K Q) indicates 3 or less category " C " results in 1946 A fair resazurin record (K Q) indicates 4 to 6 category " C " results in 1946 A bad resazurin record (K Q) indicates 7 or more category " C " results in 1946 A good count indicates 2000 or less per ml on 2 out of 3 samples examined A fair count indicates 2001 to 20,000 per ml on 2 out of 3 samples examined A bad count indicates 20,001 or more per ml on 2 out of 3 samples examined are plated using yeastrel milk agar (Min. of Health, England, Memo. 139/Foods) and the plates incubated 3 to 4 days at 30° C. A temperature of 30° C. yields more significant results than 37° C. This method is time consuming and expensive and unsatisfactory for large scale work. Moreover, for an adequate guide to the thermoduric content of any given supply a series of tests is necessary; little reliance should be placed on a single test. A more rapid, simpler, and less expensive technique has been suggested by Myers and Pence (1941, *J. Milk Tech.*, **4,** 18), and McKenzie and Lambert (1947, *SAB,* p. 19).

The normal thermoduric flora of raw milk has no influence on dye reduction tests and it is frequently observed that farms with good methylene blue or resazurin records may have milk of a high thermoduric content (*see* Table Th VII). The use of a regular thermoduric count test as an additional guide to hygienic production can therefore be emphasised. Opinions differ as to what may be regarded as a satisfactory or unsatisfactory thermoduric count of milk. It may be stated that milk with a thermoduric count > 10,000 per ml. (incubated at 30° C.) can be regarded as unsatisfactory and indicative of bad production methods.

In a series of papers McKenzie, Clegg, Thomas, Egdell, and Cuthbert have made a comprehensive review of the subject (1949, *IDC,* **2,** 536; 1948, *JSDT,* **1,** 184; (1950), *SAB,* **13,** 27, 124, 132). These reviews have discussed laboratory methods of examination, the habitat, types and distribution of thermoduric bacteria, factors influencing thermal resistance, incidence of thermoduric organisms in raw milk, effects of cooling, season and growth on milk utensils. A suggested standard technique for the laboratory pasteurisation of milk samples, rinses and swabs of milk equipment together with proposals for the interpretation of results, have also been given.

It has been shown that in determining the thermoduric bacterial content of rinses or swabs of milk equipment, prior to laboratory pasteurisation sterile skim milk should be added to the rinse or swab solution in the proportion of 4 of milk to 1 of rinse. As a rule this gives a higher thermoduric count. A temperature of 65° C. for 35 min. for laboratory pasteurisation may also give an under-estimate of the thermoduric population and the lower temperature of 63·5 ± 0·5° C. should be employed. Evidence has been obtained to show that the numbers of thermoduric bacteria show little difference in milk samples stored for 24 hr. at either 4° or 20° C., and it has been suggested that milk samples may be stored up to 24 hr. at shade atmospheric temperature prior to testing.

Some American work has suggested that quaternary ammonium compounds may have a more effective bactericidal action than hypochlorites on thermodurics.

Doetsch and Pelczar (1948, *JB,* **56,** 37) have studied the morphology and physiology of microbacteria and proposed three species, viz. *M. lacticum, M. flavum* and *Microbacterium sp.* On the other hand, Abd-el-Malek and Gibson (1952, *JDR,* **19,** 153) maintained that there is insufficient evidence to support the separation of these species from the genus *Corynebacterium.*

THERMODYNAMICS. The study of the relation of heat to mechanical energy. The whole of this vast branch of science is based on two fundamental laws (a third is also sometimes included).

(1) Following the principle of the conservation of energy, the first law states that when heat and energy are interconverted, there is neither gain nor loss. (2) From experimental evidence, the second law tells us that cold bodies do not of themselves pass on what heat they have to less cold bodies. The postulate that the entropy of all pure crystalline substances would be zero at the absolute zero of temperature is sometimes called the third law, but is seldom of practical importance to those working in the field of dairying (*see* Entropy).

THERMOMETERS. Instruments for measuring the temperature of a material. Some depend on expansion of a suitable material, usually mercury, or a liquid like alcohol, or a gas. Thermometers may be direct-reading like mercury or coloured alcohol in glass, or indirect, the reading being given on a dial, or recording, the reading causing a pen to move up or down on a chart held on a revolving drum. The second and third varieties should be constantly checked against a known accurate mercury thermometer, which in turn should be checked at intervals against a standard thermometer. This should be kept locked up by the head of the laboratory and never used for measuring temperatures in practice. *See* Instrumentation ; Pasteurisation.

There are many ways of measuring temperature, and these are variously selected by international agreement as the " correct " method for different ranges of the temperature scale. At comparatively low temperatures, thermometers depending on the expansion of a column of mercury or some other liquid such as alcohol, are used. For a certain range of temperature the electrical resistance of a single metal serves as a measure. For higher temperatures, the thermocouple is used, in which the potential set up at the junction of two different metals is measured. Very high temperatures are measured from the energy of radiation. It is not generally realised that for certain ranges of temperature these methods cannot be directly compared with one another, and that temperatures measured within different ranges cannot therefore be said strictly to constitute a single " property ", but must be defined in terms of the operation selected for measurement.

Refs.: B.S. 695 (1936) (floating); B.S. 1704 (1951) (general purpose).

THERMOMETRIC SCALES. Fahrenheit degrees may be converted to Centigrade by the formula

$$(F - 32) \times \tfrac{5}{9} = C$$

and Centigrade to Fahrenheit by the formula

$$(C \times \tfrac{9}{5}) + 32 = F$$

TABLE TS I

° *F.*	° *C.*	° *F.*	° *C.*	° *F.*	° *C*	° *F.*	° *C.*
− 4	− 20	53·6	12	93·2	34	161·6	72
− 0·4	− 18	55·5	13	95	35	165·2	74
+ 3·2	− 16	57·2	14	96·8	36	168·8	76
6·8	− 14	59	15	98·6	37	172·4	78
10·4	− 12	60·8	16	100·4	38	176	80
14	− 10	62·6	17	102·2	39	179·6	82
17·6	− 8	64·4	18	104	40	183·2	84
21·2	− 6	66·2	19	107·6	42	186·8	86
24·8	− 4	68	20	111·2	44	190·4	88
28·4	− 2	69·8	21	114·8	46	194	90
32	0	71·6	22	118·4	48	197·6	92
33·8	+ 1	73·4	23	122	50	201·2	94
35·6	2	75·2	24	125·6	52	204·8	96
37·4	3	77·0	25	129·2	54	208·4	98
39·2	4	78·8	26	132·8	56	212	100
41	5	80·6	27	136·4	58	215·6	102
42·8	6	82·4	28	140	60	219·2	104
44·6	7	84·2	29	143·6	62	222·8	106
46·4	8	86	30	147·2	64	226·4	108
48·2	9	87·8	31	150·8	66	230	110
50	10	89·6	32	154·4	68		
51·8	11	91·4	33	158	70		

It is now known that there is a lower limit to temperature, *i.e.* the temperature at which all molecular movement would cease. For many scientific purposes, it is convenient to define zero temperature at this point, while retaining the magnitude of the centigrade degree. Temperatures on the absolute scale (sometimes written °K. in honour of Lord Kelvin, and sometimes as °A, absolute) are obtained by adding 273 to the centigrade reading. Thus in absolute units, water boils at 373° A. or 373° K.

THERMOPHILIC BACTERIA IN MILK AND DAIRY PRODUCTS.

Although this contribution deals with thermophilic organisms affecting dairy products, a brief description of the salient characteristics of the group will help to a better understanding of the problem as a whole.

For a general review of thermophilic bacteria, reference can be made to the comprehensive contributions of Gaughran (1947, *BR*, **11**, 189) and Allen (1953, *BR*, **17**, 125), while earlier reviews of the problem in milk have been contributed by Robertson (1927), *N.Y. State Agr. Exp. Sta. Tech. Bull.*, 130; Prickett and Breed (1929), *N.Y State Agr. Exp. Sta. Bull.*, 571; Breed (1932), *N.Y. State Agr. Exp. Sta. Tech. Bull.* 191; Walts (1940), *Milk Plant Monthly*, **29**, (4), 29.

Definition. Thermophilic bacteria or thermophiles may be defined as organisms which are able not only to survive comparatively high temperatures (*i.e.* thermotolerant or thermoduric bacteria) but can actively proliferate at these temperatures. Cameron and Esty (1926, *J. Inf. Dis.*, **39**, 89), by analogy with anaerobes, speak of *obligate* thermophiles growing at 55° C. and failing to grow at 37° C., and *facultative* thermophiles capable of growing also at the lower temperature. The ordinary mesophiles they define as growing at 37° C. but not at 55° C. Prickett and Breed have, on the whole, followed these criteria, although Russian workers have recently restricted qualification for this group by suggesting a temperature of 60° C. for growth, and a failure to grow at 28° to 30° C. They also suggested the terms *Stenothermal* thermophiles for the true or obligate organisms, and *Eurithermal* thermophiles for the facultative group capable of growth at both 60° C. and 28° to 30° C. Bergey classifies the organisms into two main groups: (*a*) the true thermophiles having an optimum growth temperature of 60° to 70° C. and showing little or no growth below 45° C., and (*b*) the facultative group having a maximum growth temperature of 60° C. but developing also at room temperature (20° C.).

Growth at a temperature of 50° to 70° C. may be taken as an essential property of these organisms.

Characteristics of the Group. Thermophiles appear to be very widely distributed in nature and have been isolated from raw and pasteurised milk, manufactured dairy products, faeces of animals (including man, fishes, birds, and frogs), vegetables, grain, sea and fresh water, and from soils of various climates.

In spite of their ubiquity, Migula and Tsiklinsky (quoted by Gaughran, 1947) have failed to isolate them from uncultivated soil. They may therefore be species associated with living habitats and acclimatised to higher temperatures.

The outstanding characteristics of the group, when growing at optimal temperatures, are: (i) an apparent absence of any appreciable lag phase; (ii) an extremely rapid rate of growth; (iii) an equally rapid death rate, resulting in almost the self-sterilisation of the culture in a matter of hours, or even minutes.

A further characteristic is the absence of any marked growth at 20° C. or at best an extremely slow growth rate at that temperature.

Figs. Tp 1 and 2 illustrate these points. Fig. Tp 1 (Tanner and Wallace, 1925, *JB*, **10**, 421) shows the comparative growth rate of three rather slow-growing, spore-bearing thermophiles at 22° C., 37° C., and 55° C. At 55° C. the organisms reach maximum growth in the shortest time and die off equally rapidly.

Fig. Tp 2 (Hansen, 1933, *Arch. Mikrobiologie*, **4**, 23) illustrates the same phenomenon with another facultative, spore-bearing thermophile. It will be observed that with this fast growing organism the culture reaches maximum numbers at the end of only 5 hr., and decline sets in at an alarmingly rapid rate. After only 20 hr. growth at 52·3° C. the culture is practically sterile.

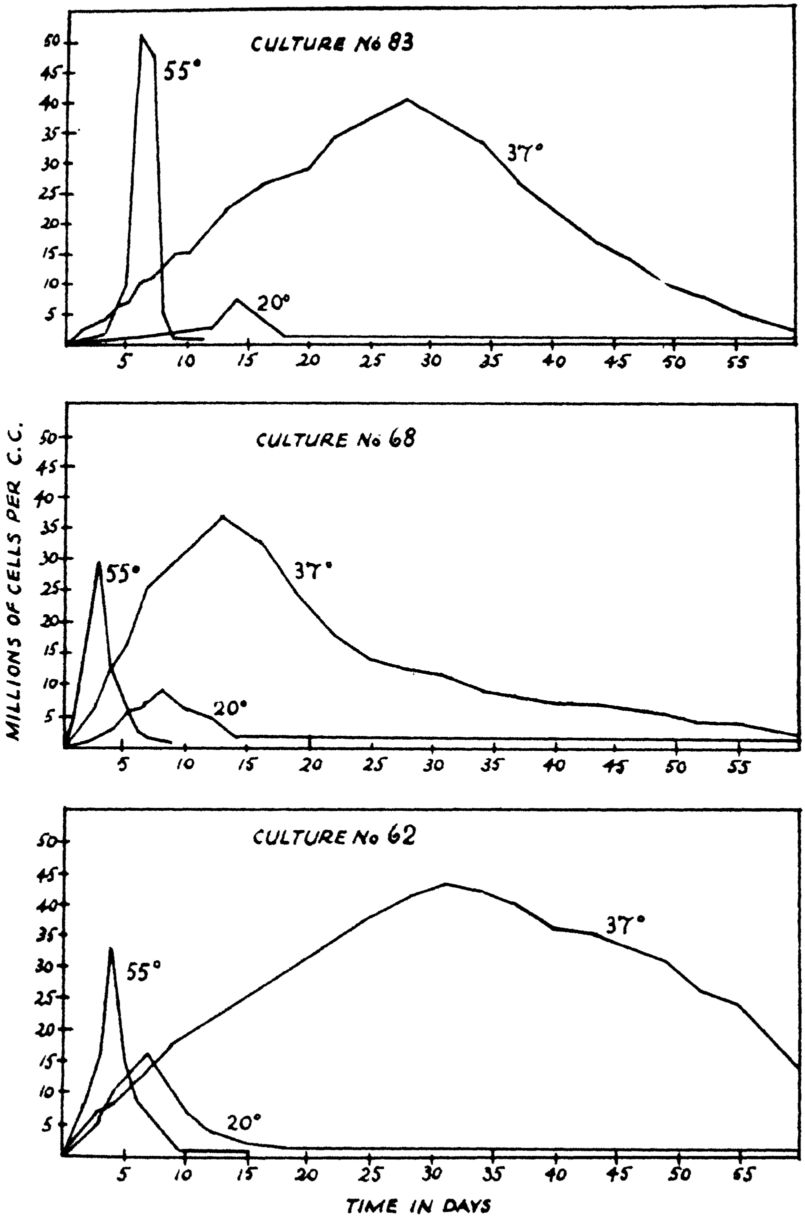
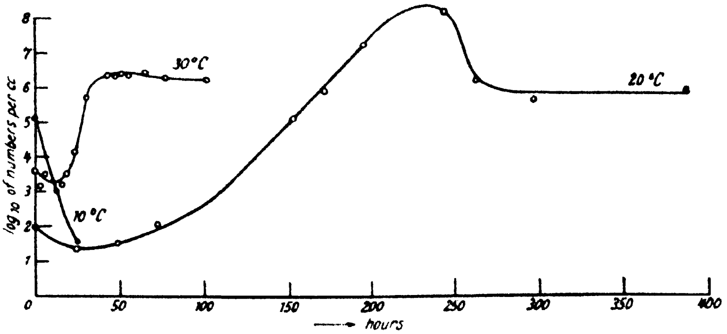
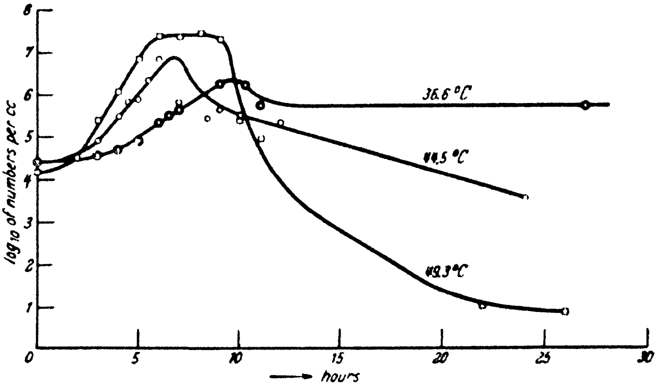


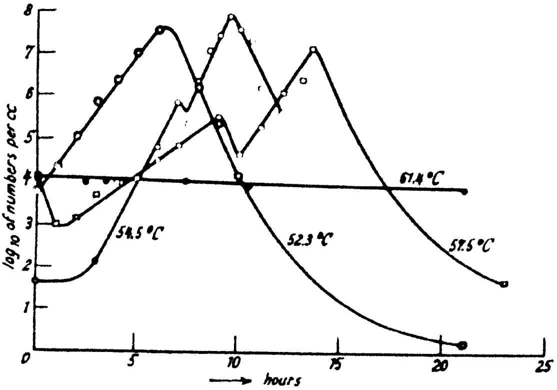
FIG. Tp 1.—*Effect of Temperature on Growth Rate of Thermophiles* (*Tanner and Wallace, by Kind Permission of Authors and the Publishers Messrs. Williams and Wilkins Co.*).



A Decimal logarithms of bacterial counts plotted against time. 10°, 20°, 30° C



B. Decimal logarithms of bacterial counts plotted against time 36.6°, 44.5°, 49.3° C.



C Decimal logarithms of bacterial counts plotted against time 52.3°, 54.5°, 57.5°, 61.4° C

FIG. Tp 2.—*Effect of Temperature on Growth Rate of Thermophiles (Hansen, by Kind Permission of Author and Publishers).*

Hansen has calculated the generation time of this organism at various temperatures (Table Tp 1) and whereas at 20° C. each generation occupies 370 min., at 54·5° C. only 16·1 min. are required. The inability of thermophiles to grow at low temperatures may be closely associated with their internal protoplasmic structure and composition.

TABLE Tp I

(Hansen, 1933)

Temp. ° C. .	20	30·3	36·6	44·5	49·3	52·3	54·5	57·5
Generation time in min. . .	370	78·5	59·5	31·8	23·4	28·6	16·1	24·4

Gaughran (1947, *JB*, **53**, 506) recently found that a large proportion of their cellular lipids consisted of higher *saturated* fats and at low temperatures the cell was unable to function owing to their solidification. The Russian workers, Imsenecki and Solnzeva (1945, *JB*, **49**, 539), observed that aeration of growing cultures of thermophiles stimulated growth and they attributed the slower rate of growth in unaerated cultures to the lower concentration of dissolved oxygen available in the medium at higher temperatures. However, aeration would also tend to remove any volatile inhibitory substances produced, *e.g.* volatile acids which, for example, *Str. thermophilus* (a thermoduric) is known to produce in greater quantities at higher temperatures. (Stern and Frazer (1941), *JB*, **42**, 479.)

The non-sporing thermophiles, *e.g. L. thermophilus*, exhibit a similar growth rate. Table Tp II (Ayers and Johnson (1924), *JB*, **9**, 285) shows that at 145° F. (62·8° C.) an almost insignificant inoculum results in a population of 84,000 in 6 hr. and 471,000 in 6·5 hr.

Problems in Holder Pasteurised Milk. The problem of thermophiles in milk results almost entirely from the introduction of milk pasteurisation in the early part of this century. Its purpose was to safeguard milk from the presence of pathogenic organisms by subjecting the milk to a heat treatment of 145° F. for 30 min. The process certainly destroyed pathogenic bacteria, but it was soon discovered that this specialised group of thermophilic bacteria, admittedly non-pathogenic, were frequently encouraged to take their place.

In the U.S.A., and later in this country, the sanitary quality of pasteurised milk was controlled by legislation which insisted on certain minimal bacterial counts, obtained by plating and incubation at 37° C. When thermophiles were present in the original milk or in the pasteurising plant, they found almost ideal conditions for rapid proliferation. A great part of the competing flora, namely the thermolabile organisms, was removed during pasteurisation, whilst another section, the thermotolerant flora, only just managed to survive. Thus, with such competition removed, the thermophiles, which thrive during pasteurisation, have a clear field for rapid proliferation.

The credit for first observing the phenomenon of an actual increase taking place during pasteurisation goes to Jacobsen (1918), *Abst. Bact.*, **2**, 215. Soon after, laboratory workers began to notice the presence of numerous tiny or " pin-point " colonies on plates of pasteurised milk. As it had to satisfy a minimal bacterial standard, " pin-point " colonies presented a rather perplexing problem to milk sanitarians and the literature of the subsequent two decades is replete with studies of the problem. The contributions of Ayers and Johnson, Fay, Prickett, Robertson and Yale in the U.S.A. are outstanding in this field.

Pin-point Colonies from Pasteurised Milk. The presence and significance of these minute colonies (on plates made from pasteurised milk and incubated at 37° C.) was recognised by Yates (1923), *Abst. Bact.*, **7**, 24. In 1924 Ayers and

TABLE Tp II
(Ayers and Johnson, 1924)
(*Count per ml. milk*)

Temp.		*Start cold milk*	*After 15 min. pre-heating*	¼ *hr.*	½ *hr.*	1 *hr.*	3 *hr.*	4 *hr.*	6 *hr.*	24 *hr.*
° C.	° F.									
30	(86)	125,000							163,000	535,000
37	(98·6)	109,000							219,000	9,400,000
50	(122)	148,000	174,000		220,000	257,000	6,700,000	16,400,000	23,000,000	
62·8	(145)	0 in 0·1 c.c.				0 in 0 1 c.c.	900	4000	84,000	
62·8		350				1700	22,000	86,000	(471,000 in 6·5 hr.)	
62·8		473,000				(2,700,000 in 2 hr)	23,700,000	35,000,000	53,000,000	
52·8		620,000	570,000		480,000	860,000	9,300,000		26,000,000	
65·3	(150)	201,000	210,000		76,000	85,000	530,000		7,100,000	
68·3	(155)	600,000	330,000		233,000	100	0 in 0·1 c.c.	0 in 0·1 c.c.	0 in 0·1 c.c.	

Johnson, in a masterly study, showed that the causative organism in their investigation was *Lactobacillus thermophilus.* The rapid rate of growth of this organism has already been mentioned. The organism was found to proliferate most rapidly in the holding tank, which was run every day continuously for a period of 7 hr. The organism grew over a temperature range of 30° to 65° C. (hence the " pin-points " on the 37° C. plate) and had its optimum temperature at 50° to 62·8° C. Its thermal death point was 71·1° C. for 30 min. and 82·8° C. (180° F.) for 2·5 min.

They suggested, therefore, that to free a plant from this type of thermophile, hot water, at 180° F. or more, should be circulated for 2·5 min., and preferably longer, between each pasteurising run. The organisms were obviously enriched during pasteurisation, as they were present only in small numbers in the raw milk supply. They also isolated an aerobic spore-former from the same hot milk, which could coagulate milk at 50° C., but as it did not grow rapidly at pasteurising temperature it was obviously less important. Fay (1927, *JB*, **13**, 347) observed that pin-point colonies could also result from the presence of thermotolerant streptococci. From plates showing these colonies, he isolated the following three groups of non-sporing organisms : (*a*) Streptococci similar in appearance to *Str. lactis.* (*b*) Streptococci occurring in short chains and of irregular morphology. (*c*) Short rod-shaped cells occurring in pairs, one member being shorter than the other (*Microbacterium* ?).

Robertson (1927, *N.Y. Sta. Agr. Exp. Station, Tech. Bull.* 131) definitely recognised that both the thermoduric *Microbacterium* of Orla Jensen and *Str. thermophilus* could be responsible for pin-point colonies. He further realised that these colonies could also be due to mesophiles and other thermoduric types.

A year later, Prickett (1928, *N.Y. State Agr. Exp. Sta., Tech. Bull.* 147) was able to show that in addition to *L. thermophilus* certain aerobic spore-formers could also produce " pin-point " colonies and give trouble during pasteurisation. Further, non-sporing rods, streptococci, micrococci, sarcinae, actinomyces, and yeasts, were also isolated from " pin-point " colonies. Only the spore-formers, however, proved to be true thermophiles. He examined numerous milk supplies for the presence of thermophiles and found them in only 25 per cent. of the supplies examined and then only in an occasional churn of any one producer. Prickett lists 10 thermophilic spore-formers, 8 of which had been previously described. He gives also a full decription of 2 new species both capable of coagulating litmus milk, *i.e. B. terminalis var. thermophilus* and *B. kaustophilus.* The former showed only faint growth at 25° C. and had an optimum temperature of 56° to 63° C.; the latter, a more obligate thermophile, showed faint growth at 37° C. and had an optimum growth temperature at 60° to 65° C. He came to the conclusion that both the thermoduric and thermophilic flora were derived from the milk, not the milk plant or equipment, and that the organisms gained entrance into the milk from the soil.

Hussong and Hammer (1928, *JB*, **15**, 179) isolated another spore-bearer, *B. calidolactis*, which gave trouble during condensing, causing the hot milk to coagulate. It proved to be an obligate thermophile growing at 55° C. in milk and glucose agar, but not on standard agar. It grew rapidly at 55° to 65° C. but failed to grow at 37° C. while at 45° C. its growth was questionable. In litmus milk it produced both reduction and coagulation.

Conditions Encouraging Thermophiles in Milk. After many of the vegetative and sporing forms had been isolated and described, attention was turned to the actual method of multiplication during pasteurisation. Search was also made for possible methods of control and prevention. Yale (1929, *N.Y. State Agr. Exp. Sta. Tech. Bull.* 156) investigated seven different milk supplies, one of which, after 3 hr. holding at 145° F., showed the presence of 6 million organisms per ml. He found that re-pasteurisation of returned milk and incorporation of drip-milk from bottle fillers contributed an inoculum of several million organisms.

Rapid increase in count was observed when the milk was " held " for periods longer than the specified 30 min., *e.g.* during hold-ups in the process, or when the plant shut down for short periods while waiting for further milk supplies.

Examination of milkstone deposits showed the presence of 1,600,000 bacteria per g. " Dead ends " on a plant, usually difficult to clean, also proved a rich source of thermophiles.

He also found that whereas one plant, which was well and regularly cleaned, produced milk with very few and at most 60,000 bacteria per ml. after 4 to 5 hr. continuous running, another, less well cleaned, produced milk containing 7,500,000 bacteria per ml. after 4 to 5 hr. In both instances thermophiles appeared to be absent from the raw milk. Some of the cultures isolated were identical with *B. kaustophilus* (Prickett).

Yale pointed out that the foam remaining in the vat was an important source of inoculum for each batch of milk entering the holder.

Rowlands and Provan (1941, *DI*, **6**, 101) illustrate admirably how the gradual " build-up " of thermophiles occurs in the holder.

Table Tp III, shows that the presence of only 10 thermophiles in the original milk may result in 100,000 during the 4th hour of a " run " and may reach millions in the 6th.

TABLE Tp III

INCREASE OF THERMOPHILES IN A PASTEURISING PLANT

(Rowlands and Provan, 1941)

Time	*Plates incubated at 37° C.*		*Plates incubated at 63° C.*
	Pasteurised	*Repasteurised*	
10.30 a.m.	97,000	28,900	Less than 10
11.30 a.m.	29,000	15,000	4,500
12.30 p.m.	23,100	7,100	13,900
1.45 p.m.	96,000	44,000	33,000
2.45 p.m.	231,000	162,000	95,000
3.45 p.m.	122,000	89,000	208,000
4.45 p.m.	98,000	110,000	Millions
5.15 p.m.	86,000	70,000	Millions

Some of Meanwell's data (1939, *DI*, **4**, 284) suggest that under factory conditions there may be a lag in thermophile multiplication in the plant (Table Tp IV). It thus appears that in holder pasteurisation an operation period of 4 to 5 hr. is sufficient to produce a thermophile " build-up " unless precautions are taken in cleaning and sterilising.

TABLE Tp IV

PLATE COUNT PER ML. AT 145° F.

(Meanwell, 1939)

	0 *hr.*	2 *hr.*	4 *hr.*	6 *hr.*	7 *hr.*
Raw milk	110	420	50	150	520
Milk entering holder .	150	500	910	7,800	> 10,000
Milk leaving holder .	4,360	26,400	187,000	508,000	Millions

Isaacs and Gordon (1943, *JB*, **45**, 51) found that the number of thermophiles tended to double for every 1·5 hr. of operation time.

Meanwell showed (Table Tp V) that, after a 6 hr. run, washing a plant through with hot water at 180° F. was effective in materially reducing the thermophile count.

The causes which give rise to and encourage thermophile growth in plant may be summarised thus: (i) Re-pasteurisation of milk. (ii) Prolonged holding of milk at high temperatures in vats or " blind ends " of piping. (iii) Continuous use of pasteuriser for more than 3 to 4 hr., without flushing through with hot solution. (iv) Use of milk filters for more than 1 to 2 hr. (v) Presence of foam from previous batch of pasteurised milk. (vi) Growth of thermophiles on walls of equipment. (vii) Presence of heavy milkstone deposits. (viii) Use of drip milk from bottle fillers. (ix) Exposure of raw milk to the sun in hot weather. (x) Inadequate or irregular cleaning of pasteurising plant.

TABLE Tp V

PLATE COUNT PER ML. AT 145° F.

(Meanwell, 1939)

Temp. of hot water rinse	0 *hr.*	1 *hr.*	2 *hr.*
180° F.	1,800	4,400	23,200
145° F.	> 100,000	1,232,000	Millions

Source and Distribution of Thermophiles. Tanner and Harding (1926, *JB*, **11**, 96), and Hansen (1929, *N. Y. State Agr. Exp. Sta., Tech. Bull.* 158), have shown that thermophiles are not found in the cow's udder. It is believed that they gain entrance to the milk from such sources as soil, compost, hay, and silage. They are present in milk in low numbers and may even show a decrease when milk is stored at room or low temperatures. Some workers have found difficulty in demonstrating their presence in raw milk owing to the low numbers in which they are frequently present. They have been reported in low numbers in American market and " certified " milks, and British workers (House and Mattick (1931), *SAB*, Paper No. 5; Thomas (1937), *Welsh J. Agr.*, **13**, 295; Bird and Egdell (1946), *DI*, **11**, 810) have rarely found them exceeding 100 organisms per ml.

The Importance of Thermophiles and Faults they Produce. There is substantial evidence to suggest that thermophiles frequently impair the flavour of milk. Apart from giving rise to undesirable high counts, Prickett (1928, *N.Y. Tech. Bull.* 147) observed that two of the species he studied produced a 0·3 per cent. acidity at 50° C. Charlton (1932, *JDS*, **15**, 393) also records high acidities and off flavours evoking consumers' complaints. The cause in this case was the use of re-pasteurised cream to adjust the fat content of the milk.

Hussong and Hammer (1928, *JB*, **15**, 179) found that *B. calidolactis* was causing the coagulation of heated milk, while Franco (1937, *Bull. Inst. Pasteur*, **35**, 377) observed the occurrence of an unpleasant taste and smell.

Mattick and Hiscox (1939, *Med. Offcr.*, **61**, 177) have recorded similar observations. As the efficiency of pasteurisation is measured by the thoroughness of phosphatase destruction, it is interesting to record that two thermophiles capable of producing phosphatase have been described (Leahy (1940), *JB*, **40**, 166; Buck (1942), *AJPH*, **32**, 1224).

Toxicity. Even when consumed in high numbers thermophilic organisms in milk appear to produce no ill effects and have no great public health significance.

They may, however, serve as an indication of inadequate plant cleaning and possibly contamination on the farm.

Guinea pigs fed on 11 cultures grown in skim milk or receiving them by intraperitoneal injection remained quite normal. (Hansen (1932), *N.Y. State Agr. Exp. Sta. Tech. Bull.* 196.)

Thermophiles in H.T.-S.T. Pasteurisation. Thermophile trouble in " holder " pasteurisation was one of the reasons which turned the attention of dairy scientists to look for alternative methods of pasteurisation. As the destruction of bacteria is a function of both temperature and time, several other combinations are theoretically and practically suitable for efficient pasteurisation. The use of higher temperatures and shorter heating times was investigated by several workers in the U.S.A. and Gt. Britain.

Experiments by Yale and Kelly (1933, *N.Y. State Agr. Exp. Sta., Bull* 630) showed that no thermophiles could grow in the H.T.-S.T. (high temperature-short time) process. Further experiments in England (Mattick and Hiscox, 1937, *World Dairy Cong.*, Berlin, **3**, 344), showed that this process not only succeeded in preventing thermophilic growth, but that it might even cause the destruction of some of these organisms.

Table Tp VI illustrates the reduction in thermophiles obtained by the H.T.-S.T. process as compared with laboratory pasteurisation at 145° F. for 30 min. Experiments in Chicago carried out by several workers during 1938-40 have fully confirmed the efficacy of the process in preventing thermophile multiplication.

TABLE Tp VI

THERMOPHILE COUNT PER ML. MILK

(Mattick and Hiscox, 1937)

Raw milk	*Lab. pasteurisation at 145° F. for 30 min.*	*H.T.-S.T. (160° F. for 15 sec.)*
6,200	6,800	1,200
126,000	230,000	17,000
17,000	17,800	1,500
40,000	60,000	3,800
18,000	11,600	2,000
44,800	56,000	3,200

TABLE Tp VII

THERMOPHILIC ORGANISMS IN MILK PASTEURISED AT 163° F. FOR 17 SEC.

(Hiscox, 1944*a*)

Date	*Plate count (yeastrel agar 63° C. 30 hr.)*	
	Raw milk	*Pasteurised milk*
20 Aug., 1942	4,000	40
27 Aug., 1942	240,000	36,000
3 Sept., 1942	128,000	34,000
22 Oct., 1942	7,300	2,300
2 Dec., 1942	70,000	3,900
28 Oct., 1943	12,500	4,600
4 Nov., 1943	60,000	36,800
18 Nov., 1943	1,780	460
9 Dec., 1943	11,900	1,410

Since the legalising of this method in England in 1941 its superiority in thermophile control over the " holder " system has been amply proved. Hiscox (1944, *JSCI*, **63**, 298) has succinctly summarised some of its advantages. Table Tp VII illustrates the thermophilic counts obtained with an H.T.-S.T. plant over a period of 2 years, the reductions in count being most convincing. Hiscox suggested that the lack of *reduction* in thermophiles observed by American workers might well be due to the slightly lower temperatures employed in their system.

Few experiments have been carried out with H.T.-S.T. and " holder " plants running in parallel. One such experiment demonstrated clearly the gradual " build up " occurring in the " holder " plant (Table Tp VIII).

TABLE Tp VIII

THERMOPHILE COUNTS (145° F.) DURING H.T.-S.T. OPERATION

(Hiscox, 1944*b* [1])

Date	*Milk*	*Approximate time of sampling*			
		½ *hr.*	2 *hr.*	4 *hr.*	7 *hr.*
5 Mar., 1936	Raw	17,000	40,000	24,000	9,600
	Pasteurised	100	800	900	23,500
12 Mar., 1936	Raw	110,000	42,000	44,800	30,000
	Pasteurised	7,000	10,000	7,600	72,000
Holder plant running in parallel	Raw				300
	Pasteurised				1,120,000

[1] Quoted by Cronshaw, " Dairy Information ", p. 537.

It appears that the higher temperature (162° F.) employed in the H.T.-S.T. system does not allow thermophiles to multiply or possibly even survive. The shorter time of holding (only a matter of seconds) is not conducive to growth. Operation of H.T.-S.T. plants during the last 12 years has so far failed to detect high thermophile counts in the process. Danger points occur of course in the regenerative section and hot filters and although operators have been running plants with impunity for 7 to 8 hr. at a stretch with no apparent failure, it is wise to flush through with hot solution after every 4 hr. of plant " run ". The greater tendency for milkstone deposition in the H.T.-S.T. system (a result of the higher temperature employed) coupled with its poorer conduction of heat may tend to encourage thermophile accumulation. Thus thorough and regular cleaning and removal of milkstone are essential for the success of the method.

Culture Media, Temperature, and Effect of Light. Most workers have used fortified media as it is generally agreed that thermophiles do not grow too well on the ordinary standard media. Since Hussong and Hammer's original observation of poor growth on standard agar, separated milk or protein digest has frequently been incorporated. Milk-Lemco-peptone-agar and Bacto-proteose-peptone have proved useful. Imsenecki and Solnzeva (1945) observed better growth in shallow layers of medium owing to the decreased oxygen concentration dissolved at the higher temperatures of incubation.

Hiscox (1945, *JDR*, **14**, 182) has observed that thermoduric bacteria were sensitive to light. Similar observations have been made with thermophiles. (Mattick (1936), *2nd Int. Congr. Microbiol.*, p. 185.)

Metal top Petri dish covers have been found most useful. Generally plates are incubated at 63° C. for 30 to 48 hr., the use of 12 to 15 ml. of medium instead of the usual 9 to 10 ml. allowing slight additional incubation. Evaporation is reduced in the incubator by exposing a dish of water.

Reduction of Methylene Blue (M.B.). Harding and Ward (1928, *Pub. Hlth. J.*, **19,** 162) and Thomas (1937) found that reduction times of M.B. at 63° C. correlated fairly well with the number of thermophiles present. This too seems to have been the experience of Rowlands and Provan (1941, *SAB*, 36). Bird and Egdell (1945, *DI*, **10,** 266) have recently reported an interesting case in which thermophiles were responsible for rapid dye reduction at 37° C. although there was little thermophile growth at that temperature. The organisms were spore bearers similar to *B. calidolactis* (Hussong and Hammer) and two cultures of *L. thermophilus.* Nichols (1939, *JDR*, **10,** 202) found the test at 63° C. useful in assessing milk powders.

Methods of Prevention. Apart from the causes of thermophile "build-up" enumerated earlier it has been observed by several workers that rapid cooling and storage at low temperatures are effective in preventing or reducing thermophile growth. Ayers and Johnson (1924) observed that *L. thermophilus* tended to die out more rapidly in milk stored at 39·2° F. than at 68° F. Macy (1939, *Ass. Bull. Int. Ass. Milk Dlrs.*, **31,** 179) noted a similar decrease occurring in pasteurised milk held at 40° F. Provan and Rowlands (1941) confirmed also that there is a progressive decrease in thermophile content when milk is stored at low temperatures. They pointed out too that the age of the sample can be an important factor in assessing the original thermophile content of the milk.

Thermophilic Species Isolated from Milk. Apart from the aerobic spore formers and *L. thermophilus*, actinomyces have also been isolated. A full description of *L. thermophilus* has been given by Ayers and Johnson (1924) and Charlton (1932). Hussong and Hammer (1932, *Iowa St. Coll. J. Sc.*, **6,** 89), have described fully the characters of *B. calidolactis* while Prickett (1928) has given a full description of *B. terminalis var. thermophilus* and *B. kaustophilus* first isolated by him. The same paper includes a description of the following eight species found by him to occur in milk :

B. subtilis Cohn
B. michaelisii
B. calidus Blau
B. thermoalimentophilus
B. aerothermophilus
B. thermoliquifaciens
B. non-diastaticus
B. calidolactis

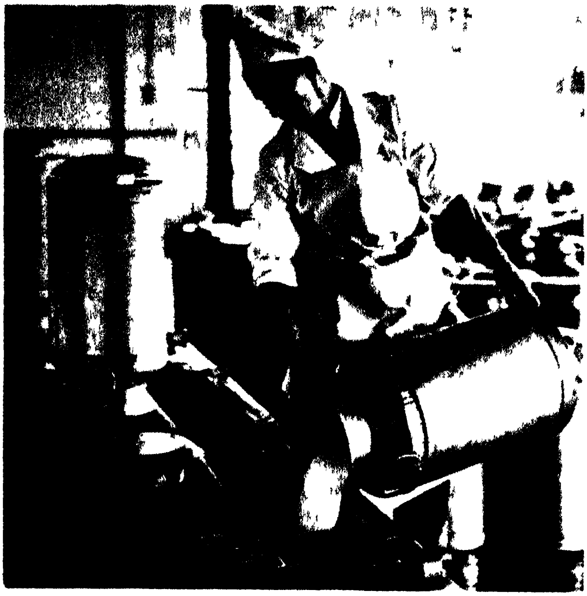
Bergey (1948) lists twenty species of thermophiles and classifies them into three groups on the basis of spore morphology and position.

Groppali (1937, *Zbl. Bakt. I*, Ref. **124,** 192) has made a study of thermophiles occurring in raw and pasteurised milk.

Thomas (*Welsh J. Agr.* (1937), **13,** 295) observed that most of his aerobic thermophiles were Gram-negative in young culture. This may possibly explain the observation of Wilson *et al.* that some thermophiles occurring in milk are Gram-negative pleomorphic rods. Donk (1920, *JB*, **5,** 373) has described a Gram-negative spore-bearer isolated from corn products.

Actinmoyces. Several species occurring in milk have been observed by Eckford (1927, *Am. J. Hyg.*, **7,** 201), Hansen (1929), and Higginbottom (1943, *SAB*, p. 22) who observed them in roller dried milks. Bernstein and Morton (1943, *JB*, **27,** 625) have described a species occurring in cheese.

Thermophiles in Dairy Products. ***Evaporated milk.*** Hammer (1915), isolated *B. coagulans* and found it to grow slowly at 37° C. and more rapidly at 55° C. In milk it produced a clot in 3 to 4 days. Hussong and Hammer (1931), (*loc. cit.*), found that *B. calidolactis* could cause souring and curdling of the product. Nichols (1939, *JDR*, **10,** 202) concludes that evaporated milk produced in this country is generally free from thermophiles.

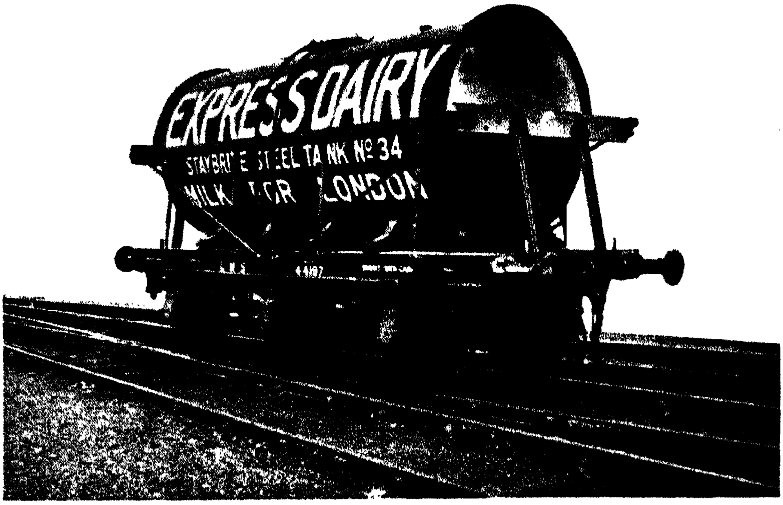


[*By courtesy of United Dairies Ltd*

FIG. Ti 1.—"*Tipping*" *a Producer's Milk at a Country Creamery (Tipping Tank)*

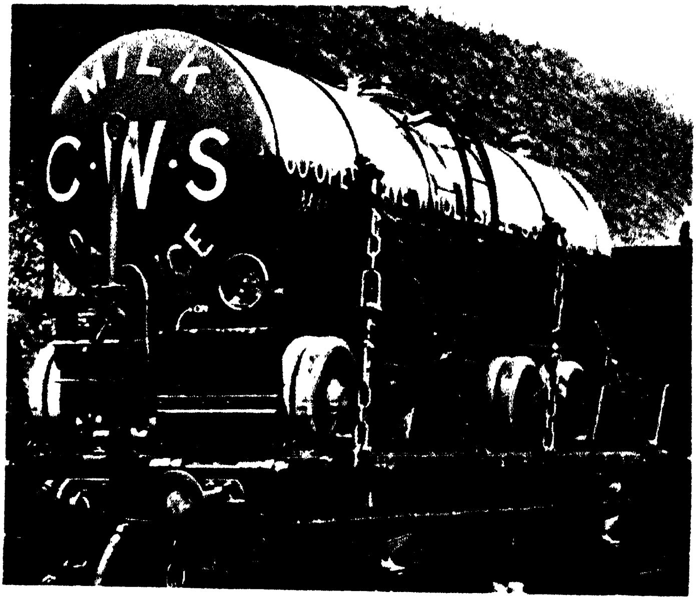
[*By courtesy of Express Dairy Co. Ltd*

FIG. Tr 1.—*Road Tanker,* 3000 *gal.*



[*By courtesy of Express Dairy Co. Ltd.*

FIG. Tr 2.—*Rail Tanker*, 3000 *gal.*



[*By courtesy of C.W.S. Ltd.*

FIG. Tr 3.—*Road-rail Tanker on Rail.*

Sterilised milk. Morgan (1943) *SAB*, p. 31) mentions *B. thermoacidurans* as the cause of bitterness, and that it can produce lactic acid both at 55° C. and 37° C. He found it to grow readily at low temperatures.

Milk powder. Hucker and Hucker (1929, *N.Y. State Agr. Exp. Sta., Tech. Bull.* 153) observed fairly high thermophile counts in powdered infant foods. Methods of processing have since considerably improved. Nichols (1939) isolated *B. calidolactis* from plates at 55° C. which produced acid coagulation in milk. Higginbottom (1943, *SAB*, p. 22) has also noted high thermophile counts in roller dried milk. Recent work by Mattick *et al.* (1943, *JDR*, **14**, 143) and Findlay *et al.* (1946, *JDR*, **14**, 378) clearly shows that with proper control and an adequate pre-heating temperature thermophile counts in spray dried milks are very low. The low moisture content and comparatively low storage temperatures probably act as sufficient deterrents for thermophile growth or germination.

THICKENING. *See* Condensed milk.

THICKENING SUBSTANCES. " Viscogen " (calcium saccharate), starch, and gelatin have been used for thickening cream.

THIEF. A tube of glass or metal about 3 ft. long and ½ in. diameter open at both ends. The tube is dipped into the milk, the upper end closed by the thumb, and the tube then lifted and milk allowed to run into a sample bottle. *See* Sampling.

THREE TIMES DAILY MILKING. Thrice daily milking usually increases the yield but is only an economic proposition for heavy yielders, especially Friesians. Such cows may be milked three times a day during the early or flush period of lactation. *See* Composition, factors affecting ; Management of dairy cattle.

" THUMB-NAIL TEST." A test for dirty churns in which the thumb nail is drawn up the inside of the shoulder of the churn. A yellow slime is readily detected if present.

THUNDER, EFFECT ON MILK. Although thunder is commonly supposed to " turn " milk, there is no conclusive evidence that thunder itself does so. Souring is probably due to the high prevailing temperatures.

THUNK. A wart-like obstruction in the teat canal.

THYMOL. A phenolic substance $CH_3 . C_6H_4OH$ sometimes used for preserving milk samples for analysis. *See* Preservation of samples.

THYROID. An endocrine or ductless gland in the neck secreting thyroxine. *See* Hormones ; Milk secretion.

THYROXIN. The active, iodine-containing, chemical agent or hormone secreted by the thyroid gland, and which plays an important part in controlling metabolism. *See* Hormones ; Milk secretion.

TILSIT, TILSITER. *See* Cheese, p. 203.

TIMES OF MILKING. From the point of view of the cow, and obtaining the greatest yield and even fat content, cows should be milked at 12 hr. intervals. In practice the intervals are unequal, and more unequal in winter when the afternoon milking is usually earlier and the morning later. Times of collection may also influence milking times. *See* Collin's rule ; Composition, factors affecting ; Management of dairy cattle.

TIMOTHY GRASS, HAY. A hardy, fool-proof crop for hay but low in protein. *See* Feeding.

TIN. Tin-plated mild steel is commonly used for plant, churns, etc., in the dairy industry as this material is cheap, strong, reasonably durable and produces no taint or other ill-effect in milk. Tin-plated copper was formerly used but is now seen only in the more backward dairies, as on wearing the copper may become exposed and by dissolving in the milk cause oxidised taints (p. 475).

If tin-plated churns are cleaned by a hot detergent solution of high alkalinity, at least 10 per cent. sodium sulphite and some silicate should be included in the detergent to prevent corrosion of the tin. *See* Cleaning; Detergents; Metals.

Ref. : Lewis (1947), *JSDT*, **1**, 27.

TINFOIL. *See* Packaging.

"TIPPING." The pouring of milk from churns into a tipping tank (if the milk is bought by volume) or into a weigh tank (if the milk is bought by weight) (Fig. Ti 1). Immediately before tipping, the churn of milk is examined for taint or souring. *See* Management of creameries; Platform testing.

TITRATABLE ACIDITY. *See* Acidity.

TON. 2240 lb.; 1·016 metric tons or 1016 kilograms.

TORQUE. A force producing rotation, or tending to produce it.

TORULA. The name commonly used for the genus of non-sporing yeasts but earlier used for a genus of moulds. There is a trend to adopt the name *Torulopsis* for the non-sporing yeasts. *See* Moulds; Yeasts.

Ref.: Smith.

TOTAL SOLIDS AND SOLIDS-NOT-FAT IN MILK. Formulae for Calculating the Percentages of, from the Fat Content and Specific Gravity or Density. (i) ***Richmond's formula.*** Based on fat content by Gerber method, and specific gravity at 60° F. as determined by a lactometer made for this purpose.

$$\text{T.S.} = 0{\cdot}25\,G + 1{\cdot}2\,F + 0{\cdot}14$$

where T.S. = total solids percentage; F = fat; G = lactometer degrees, *i.e.* 1000 (S.G. — 1) at 60° F.

Lactometer readings taken at temperatures other than 60° F. are corrected to 60° F. by adding or subtracting 0·1 lactometer degree for each degree F. above or below 60° F.

(ii) ***British Standards Institution formula.*** In 1937 the B.S.I. drew up a specification for lactometers designed to record the density of milk as g. per ml. at 20° C. These lactometers or densimeters are now available and, when used, the following modification of Richmond's formula should be applied:

$$\text{T.S.} = 0{\cdot}25\,D + 1{\cdot}21\,F + 0{\cdot}66$$

where D = lactometer degrees, *i.e.* 1000 (density — 1) at 20° C.

The correct formula must be used for each lactometer.

For a detailed description of the advantages and use of the density lactometer and tables which render the calculation unnecessary and give the necessary temperature corrections, *see* B.S.I. Specification No. 734, " Density Hydrometers for Use in Milk ".

Refs.: Leggatt (1953), *N*, **171**, 1028 (det. by oxidimetry); Davis (1952), *A*, **77**, 499.

TOTAL SOLIDS, GRAVIMETRIC DETERMINATION OF. When accurate results are required, the conventional method consists of drying 3 to 5 g. of milk at 100° C. until differences in consecutive weighings are not more than 0·2 mg., usually for 3 to 4 hr. For a rapid method for dealing with large numbers of milk samples, drying 1 ml. in small aluminium dishes and weighing rapidly by an air-damped balance is recommended (Aschaffenburg, 1938, *JSCI*, **57**, 319 and Golding, 1934, *A*, **59**, 468).

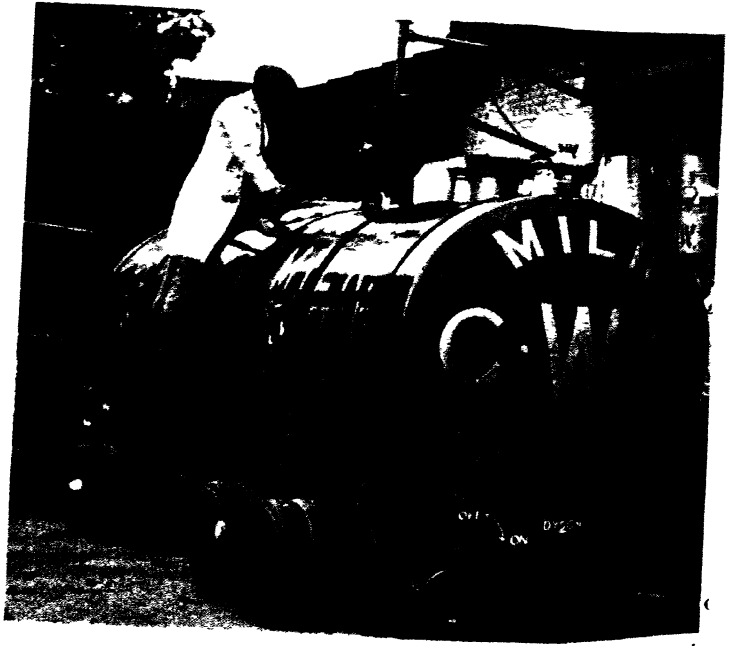
Ref.: Ystgaard *et al.* (1951), *JDS*, **34**, 695.

TOXICITY. The ability of poisonous substances whether of bacterial, vegetable, animal, or synthetic origin to kill animals and man. It is usually measured by the *Lethal Dose* (LD) which is the amount required to kill on the average a given proportion, *e.g.* 50 per cent. of the experimental animals in terms of per animal or per kilogram bodyweight. Bacterial toxins are the most powerful known. Thus, the LD for an adult man is: atropine 130 mg., strychnine 35 mg., cobra venom 4·5 mg., tetanus toxin 0·2 mg. or less. *See* Food poisoning.

Ref.: Wilson and Miles.

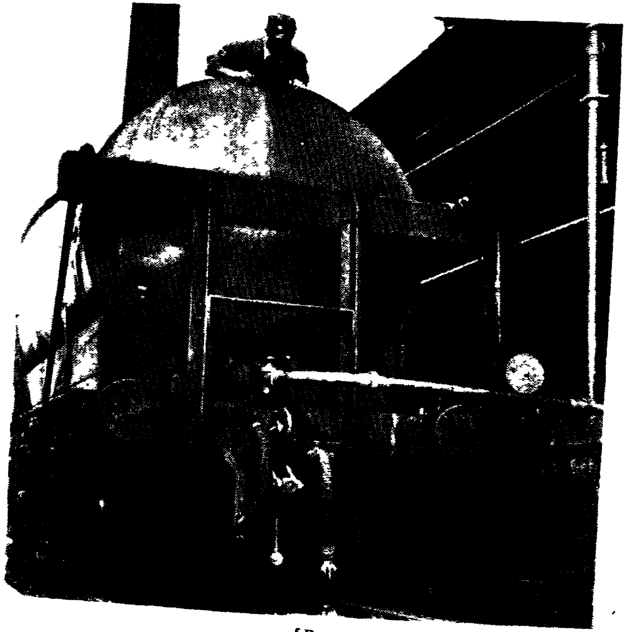
TOXINS. Highly poisonous substances, usually protein in nature, produced by certain micro-organisms, such as *Cl. tetani* and *Cl. botulinum*. *See* Food poisoning; Toxicity.

Ref.: Wilson and Miles.



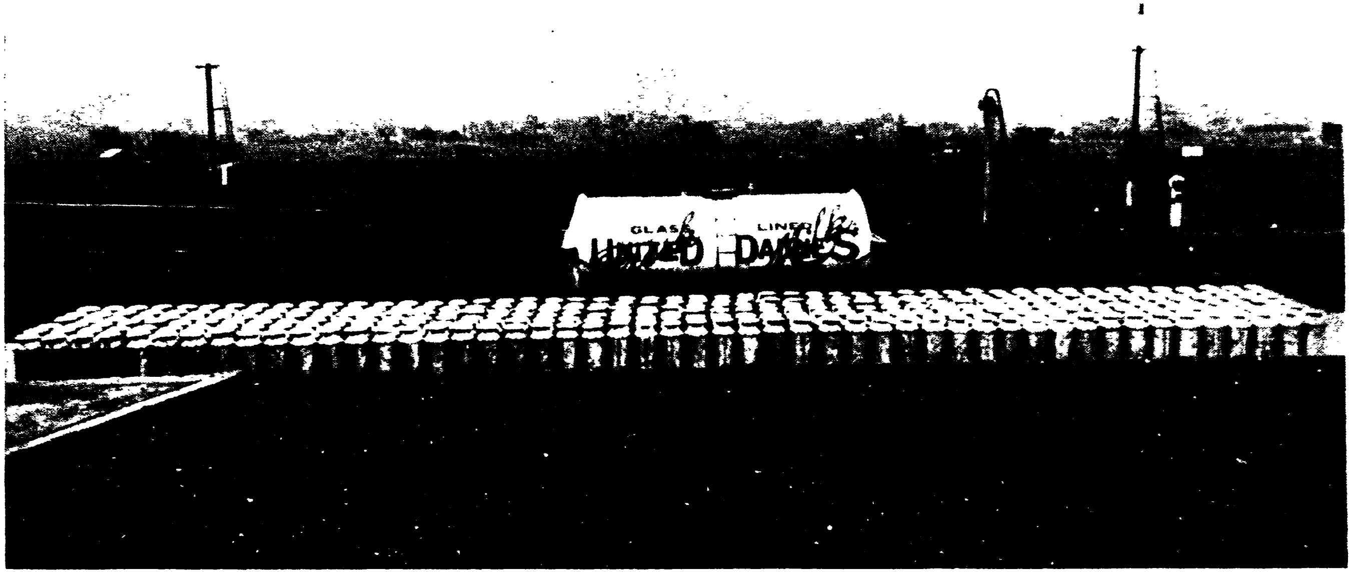
[By courtesy of C W.S. Ltd.

FIG. Tr 4.—*Filling a Tanker at a Collecting Depot.*



[*By courtesy of United Dairies Ltd*

FIG. Tr 5.—*Discharging a 3000 gal. Rail Tanker at a London Pasteurising Depot.*



[*By courtesy of United Dairies Ltd.*

FIG. Tr 6.—*The Enormous Saving of Space achieved by a Milk Tanker. These Churns would be required for the same Volume of Milk.*

TRACE ELEMENTS. *See* Constituents.

Refs.: Richmond; Davies; Sandell (1950), *Colorimetric Determination of Traces of Metals;* Perrin *et al.* (1951), *JDR*, **18,** 77 (Cu and Fe); Archibald (1951), *JDS*, **34,** 1026 (Mo); *Refs.:* Nickel Co. (1946), *Trace Elements in Agriculture*, London; Whalley (1937), *Bibliography on the Influence of Mineral Deficiencies on Growth and Reproduction of Farm Animals*, Ottawa; Soc. Publ. Anal. (1934), *Bibliography of the More Important Heavy Metals Occurring in Food and Biological Material;* Cuthbertson (1948), *CI*, p. 391; Monier-Williams (1949), *Trace Elements in Food*, London.

TRANSPORT. The proper utilisation of the total milk production of the country, relies almost entirely on the flexibility of the transport system, which extends from farm to the household.

Milk is obviously a highly perishable commodity susceptible to the slightest changes in temperature, and very easily contaminated, so that the greatest care must be taken at all stages of cooling, pasteurising, bottling, and transporting.

Speed is a vital and very essential factor, the quality of the milk varying inversely with the time expended in transporting, processing and bottling, and from the moment the churns are collected from the 157,000 or more individual farmers, the dairy industry works to a time-table within extremely narrow limits.

Collection lorries are carefully routed to give maximum practical vehicle loadings at all times, to ensure economy in manpower, fuel, etc., at the points of first reception (cooling stations). Such collection schedules must have regard to the hourly plant capacity of the particular cooling station which the vehicles are supplying, and the times at which the milk has to be dispatched, either by road or rail transport, to fit in with the required arrival times at the various processing centres in the large consuming areas where pasteurisation and bottling for retail delivery take place.

Supply of, and demand for, milk, even with present day rationalisation, are subject to great seasonal fluctuations and constant vigilance must be maintained to ensure the correct quantities of bulk milk arriving at the right consuming centres at the proper times.

Farm collection lorries are usually of the 3-ton open platform type, sturdily built to withstand the continual impact of heavy churns of 10, 12, or 17 gal. capacity. A high standard of maintenance is necessary owing to the arduous nature of their work, which takes them over farm tracks and narrow unmade roads, which are often rendered almost impassable during severe weather. Tyre wear is considerably above normal as a result, and petrol consumption is rather higher than for similar vehicles employed on ordinary work over well-made roads.

Each collection journey is carefully routed to ensure a steady flow of raw milk through the cooling plant throughout the whole of the working day, thus avoiding congestion and consequent delays on the one hand and spasmodic operation of the plant on the other.

Clean, freshly sterilised churns are sent out from the cooling station and delivered to the individual farmer at the time of collection of the full churns. All churns are clearly labelled with the farmer's name and quantity of milk in each churn, so that quick identification is possible at any time.

These "cooling stations" or points of first reception, are usually situated in the centre of heavy milk-producing areas, and operate their own fleets of vehicles with a transport department an integral part of the whole. Service vehicles, at set periods, replace those on regular runs, so that each vehicle in turn visits the maintenance department for service and repair. Spare vehicles are available for immediate replacement in the event of any regular collection vehicle breaking down.

Bulk Transport. The road transport of milk in bulk is a highly specialised undertaking, involving the employment of long-distance drivers with years of training in the milk industry. Careless handling of a milk tanker on the road can quite easily result in the loss of the load, through its being " shaken up " in transit.

The type of vehicle most favoured for bulk transport is the rigid eight-wheeler, or the heavy articulated vehicle, each with a carrying capacity of approximately 3000 gal. (Fig. Tr 1). Rail tankers are used where circumstances permit (Fig. Tr 2), and road-rail tankers are sometimes used (Figs. Tr 3 and 4).

Here again, a very high standard of maintenance is necessary, as many journeys are over distances of 100 miles or more. Breakdowns *en route* can be a very costly affair, as a delay in arriving at the processing centre may mean that the whole centre, involving some hundreds of staff, is brought to a standstill. Running repairs, such as broken feed pipes, punctures, etc., are normally dealt with by the drivers themselves, and they can call on certain garages for assistance where necessary.

Breakdown vehicles and crews are held in reserve to deal expeditiously with any emergency call which may be received during the day or night. Many and ingenious are the methods employed by these experienced crews to get the milk in " on time ".

The tanker itself is actually a shell within a shell. The actual container, or inner shell, is fabricated of some material impervious to the action of milk, which has a highly corrosive effect on some metals. Of the various materials used (aluminium, glass, lithcote, stainless steel, etc.), stainless steel seems to be gaining in popularity, not only by reason of its high resistance to the action of milk, but, because of the high polish possible on its surface and the closeness of its grain; it is much easier to clean and sterilise than most other materials, an important feature where milk is concerned. In addition it is much less liable to impact damage than many other types.

The tank must be built to withstand pressure, as in many instances air pressure is used to unload the milk.

Baffle plates cannot be fitted inside the tank, as this would tend to make really efficient sterilising impossible. For this reason it is necessary that the tank be full, or nearly so, when travelling, to avoid " surging " and consequent " buttering " of the milk. Dipsticks of stainless steel for measuring the quantities of milk in the tanks are calibrated in inches and measurements are taken from the top of the tank to the level of the milk. Carefully prepared calibration charts of every milk tank used are kept at the main centres for reference purposes.

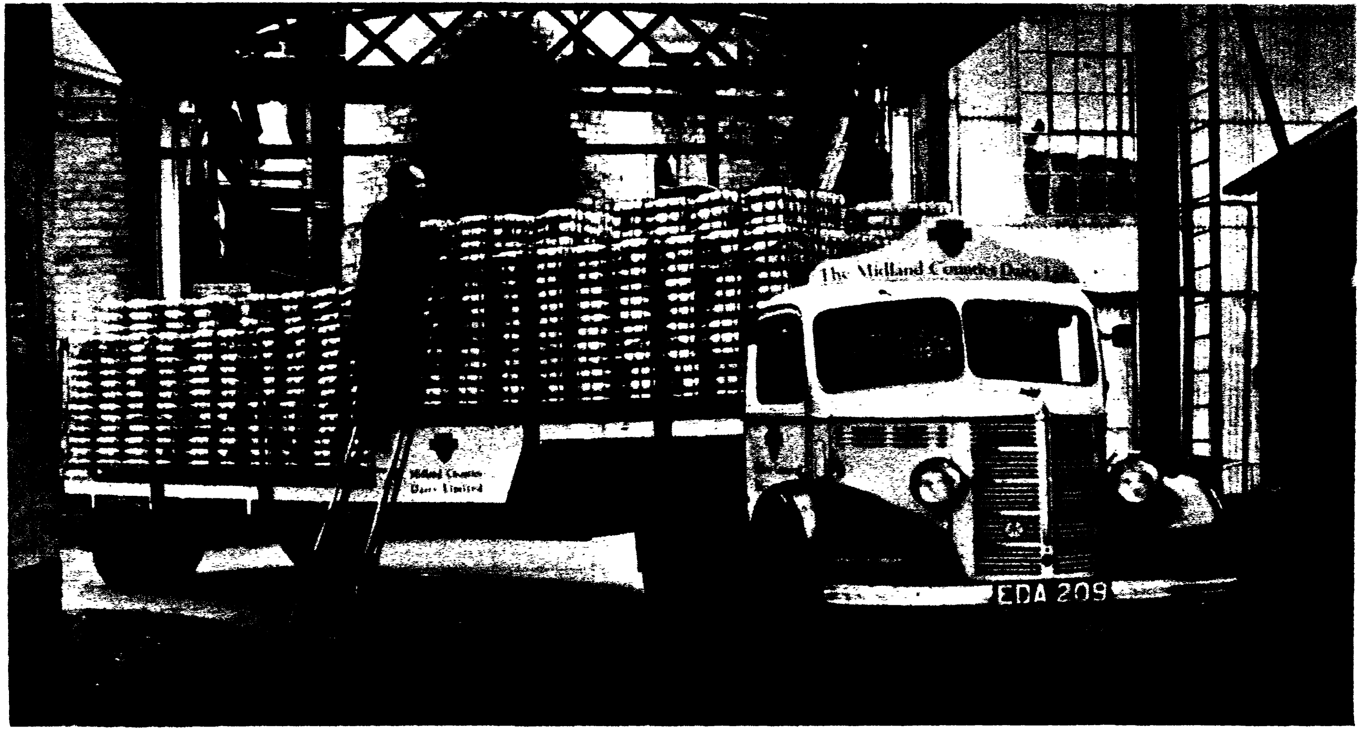
The inner container is encased in several inches thickness of some insulating material, such as granulated cork, spun glass, etc., this being held in place by the outer shell, which is actually a protective covering of sheet steel or aluminium.

Insulation plays a very important part in the successful transport of milk in bulk, it being vitally necessary to " hold " the low temperature at which the milk is pumped into the tank, until it reaches the processing centre. Careful insulation ensures also that sudden changes in atmospheric temperatures (a sudden thunderstorm for instance) do not affect the milk during its long journey.

On arrival at the processing centre (again at a pre-determined time) a test is taken of the milk, to ascertain that it is of the standard required, before unloading is commenced. Subject to test being satisfactory, the tank outlet is connected to the pump by flexible, sterilised couplings and the milk is pumped up to the holding tanks (Fig. Tr 5).

After emptying, the tank is washed out with high pressure hoses and detergents, and is then subjected to a long and vigorous process of sterilisation by means of high pressure steam pipes. All movable parts, such as pressure valves, outlet cocks, etc., are dismantled and subjected to the same treatment. A very high standard of cleanliness is essential, as the slightest trace of milk left in the tank may result in the whole of the next load being ruined.

The vehicle is next driven into the maintenance bay, where it is serviced, greased, filled up with fuel, oil and water, and prepared for its next journey.


The Midland Counties Dairy Ltd
Midland Counties Dairy Limited
EDA 209

[By courtesy of Midland Counties Dairy Ltd.

FIG. Tr 7.—*Articulated Vehicle for Dispatch of Sterilised Milk.*

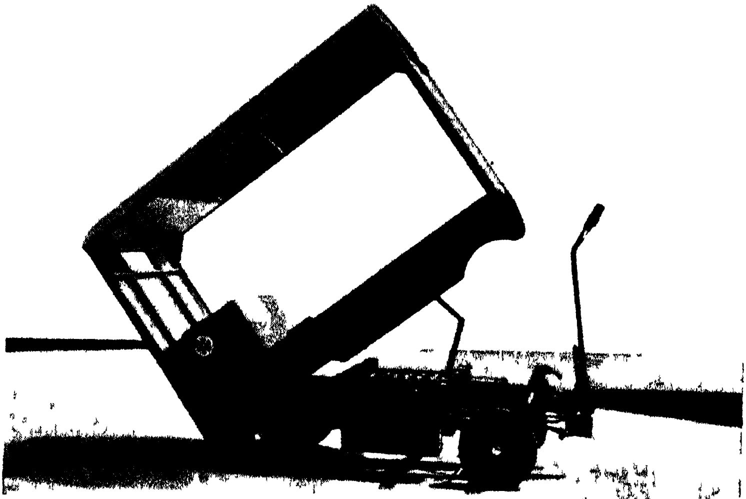


FIG Tr 8 *Electruk with L Type Dairy Body raised to show Built-in Body Prop and ease of access to Chassis*

[Photos by courtesy of T H Lewis Ltd

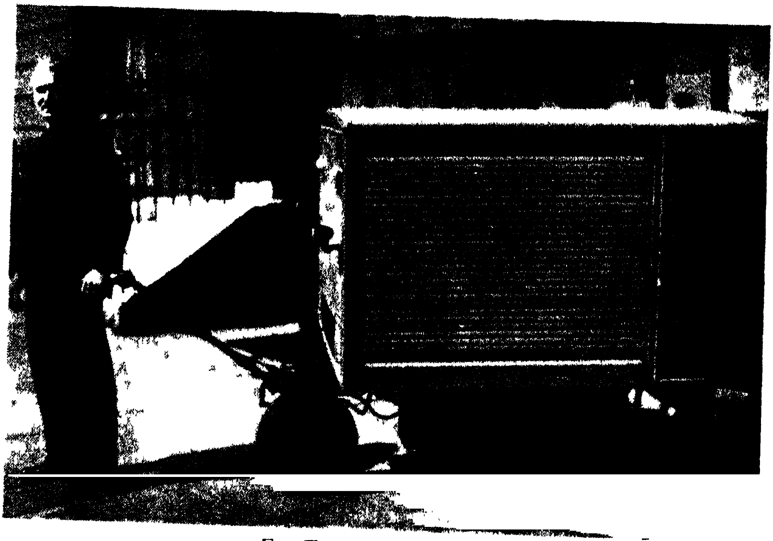


FIG Tr 9 —*Electric Pram*

Some idea of the saving in transport space by using tankers is given in Fig. Tr 6 which shows the number of churns required for the milk accommodated in a 3000 gal. tanker.

In the wholesale delivery of bottled milk to retail branches for eventual distribution to customers, many different methods are employed, varying according to output of the processing centres, size of retail branches, distances and areas to be covered, etc. In the example here illustrated, a very large number of small retail branches in a relatively small area are supplied from one processing centre, the same system being duplicated over each of the respective areas supplied.

The vehicles employed are 5 ton box vans, fitted with roller shutters at rear and side, and with a carrying capacity of just over 500 gal. in bottles. The whole fleet, spread over all processing centres, is standardised so that interchangeability between centres is possible. This standardisation ensures repairs and exchanges being carried out without loss of time, and avoids frantic searching through stores departments for special spare parts for specific makes of vehicle. The total amount of spares required to be held in stock is thus kept to a minimum consistent with safety.

The bodies of these vehicles (again of standard dimensions and shape) are specially built to give a maximum useful life consistent with the heavy work they are called upon to perform. The floors are fitted with heavy steel runners to enable the stacks of crates to slide freely, and at the same time afford protection to the timber flooring. The loading height has been reduced as much as possible to save heavy strain when unloading at branches where no bank is available.

All vehicles are hosed down frequently during the day to avoid milk souring and coagulating in corners and inaccessible parts of the chassis. Slots in the flooring assist in carrying away the water and milk.

The vehicles are in service about 18 hr. per day, Sundays and Bank Holidays included, each vehicle being operated by two crews, each working a 9 hr. shift. A 24 hr. breakdown and repairs service is maintained, ready to deal with any trouble at any time of the day or night. A small slip pasted in the cab of each vehicle reminds the driver of what to do in the event of a breakdown on the road, and it is very seldom any load is delayed more than an hour as the result of mechanical trouble. An efficient system involving the replacement of duty vehicles with " spares " at set times ensures that all vehicles receive service and inspection at frequent intervals.

Loads and journeys, distances between centres and retail branches, etc., are carefully mapped out, each crew being allotted four deliveries per 9 hr. day. Special features at the retail branches, such as difficulty of access, absence of unloading banks, length of " pull " from vehicles to cold store, traffic conditions *en route*, all have to be taken into consideration when compiling the " routing " schedules, to ensure a steady extraction of cased and bottled milk as it comes off the machines, and, equally important, a constant supply of empty bottles to feed the washers. Exhibitions, processions, trade shows, etc., with their consequent crowds and congestion at certain times and places, all have their own little problems to be dealt with by the transport department, the " nerve centre " of which must be on duty, ready for all or any eventualities, 24 hr. per day, 365 days a year. It must keep in constant touch with all processing departments, ready at a moment's notice to deal with fluctuations in supply, dairy breakdowns, fog, snow, sudden temperature changes, and the hundred and one other emergencies, which, if not dealt with in time, might jeopardise the peace and good order of thousands of families who now take as a matter of course the arrival on their doorstep each morning of the familiar pint bottle.

There are many other different methods of transporting bottled milk from processing depots to the retail depots; one that is coming into some prominence at the moment is the use of trailers which can be taken straight into a cold store and pulled out next morning, which saves unloading at the retail branch.

TRANSPORT

Vehicles are generally used to suit the individual requirements of the depots serviced and methods adopted for mechanical handling, which are covered in another section.

A special type of articulated vehicle used for sterilised milk bottles packed horizontally in special quick-release crates is illustrated in Fig. Tr 7.

Retail. This must be considered in several groups or classes, each class having its individual function according to district, distance, size of round, etc. The transport used in retail distribution is entirely different from that mentioned in the previous part of the paper as various different types are used, whereas almost 100 per cent. of the collection and distribution to retail centres is done by motor vehicle. Taking each class in turn starting with the least expensive type first:

Push pram. This form of transport is rapidly disappearing but in the large towns, especially London, is used quite considerably especially by the smaller dairymen. Its radius is very limited, the ground must be flat and the maximum capacity in one load would be between 30 and 40 gal. In 10 years' time it is very doubtful if there will be any left.

Electric pram, pedestrian operated. This form of transport commenced about 1936 and made steady if slow progress before the war, but during the war and since it has increased very considerably, mainly probably because of the blocking of the rounds, and big loads can be delivered. Capacity varies from 50 to 100 gal. per load and radius would be 10 to 12 miles according to number of stops, size of load, contour of ground, etc. These vehicles are now all being made as leaders with the driver walking in front (Figs. Tr 8 and 9). They are either on three wheels or four wheels, being generally directly driven from a small H.P. motor with 24 volt battery. Although the better makes are now being fitted with a differential and normal drive, high pressure tyres are used and some vehicles have automatic brakes when the handle is released. Bodies are made for nearly all the milk to go inside with perhaps one row on the roof. These vehicles are charged through small Westinghouse rectifiers, mostly at a very low cost according naturally to the rate of electricity. The rough cost to run these vehicles would be about 30s. per week. It is considered that there should be a great future for this type of vehicle, and in the near future it will probably be the most used and economical vehicle in the trade. It appears that if the price could be reduced a great deal more would be used.

Horse-drawn vehicles. This is the most popular mode of delivery in this country, and certainly is the cheapest where an electric pram cannot be used (Fig. Tr 10). There are scores of different types of vans, floats and trollies used, as localities seem to favour their own types. The box-van type used in London appears to be superseded by a van originally made by Creasey where the man can step from the ground into the van having milk both in front and behind him ; this saves a tremendous amount of time against climbing up on the seat. These vehicles are generally rubber-tyred and have a long life. Sizes vary but they have been seen with 150 gal. of milk. This type of vehicle will do up to about 20 miles a day if a good cob is available. Cobs do not appear to have increased in price in proportion to the rest of the turnout as they are about 20 per. cent. dearer than before the war, and there always appears to be a good supply, especially from Wales. It is difficult to go into figures of cost as so many points have to be taken into consideration, such as if a horseman has to be employed and so on. The probable cost for the whole outfit would work out at between £2 and £3 per week.

Large electric vehicles. This vehicle can be used where the distance is too great for horses, and the mileage is not more than 30 miles per day. This type of vehicle has been on the road a good many years, but it was not until about 1934 that any quantity were being used. Unfortunately during the war they were almost unobtainable, and the price now is much too high ; if, however, this price could be reduced and a lighter type of battery fitted they would no doubt replace the horse

[By courtesy of United Dairies Ltd.

FIG. Tr 10.—*Loading Crates Direct from the Conveyer into the Retail Delivery Van.*

to a great extent. They have many advantages being clean, silent, etc., and can be used where it is impossible to get stables for horses. Capacities vary from 10 cwt. to 30 cwt., but this varies on so many other factors as stated for the electric pram, but to which must be added the weight of the battery; this is again controlled by speed required, distance to go, number of stops, contour of ground, etc.

Batteries generally have a 3 years' life, but are costing in the region of £200 to replace. The cost of these vehicles would be in the region of £5 to £6 per week.

Motor vehicles. The usual types used are the 5 and 10 cwt. type, and are used mainly in country districts. The running cost of these is generally very high and they should only be used where it is impossible to use any other type of vehicle. Operators of these vehicles do not generally appreciate the cost of running, as short runs and many stops are excessively heavy on every part of the vehicle, added to the fact that they are awkward to work from.

General. All types of vehicles used should have good maintenance; the batteries on the battery vehicles must be topped up weekly with distilled water and care must be taken to see that the right level is maintained. Greasing is of prime importance together with the care of tyres. These are too often forgotten and can make a tremendous difference to running costs.

Vehicles should not be overloaded ; it is far better to make an extra trip.

Conclusion. No definite conclusion can be made as to what type of transport is the best as they all have their various spheres of use, and in large businesses all types are used.

It is generally found, however, that in the smaller types of businesses running only a few rounds, if possible it is better to keep to the one type of vehicle. *See* Bulk farm collection; Costings; Management of creameries, of pasteurising depots.

Refs.: Bauer (1953) *IDC*, **3**, 1612; Inglis (1953), *JSDT*, **6**, 160 (Scotland); Roadhouse and Henderson; Sanders (1951), *D*, **68**, 79, 203 (retail); Bergman and Rahmn (1949), *IDC*, **1**, 424 (effect on milk quality); Bird *et al.* (1949), *IDC*, **4**, 151; Rautavaara, 181; Green, 197; Ritchie (1951), *DI*, **16**, 736 (tankers).

TRAPPIST. *See* Cheese, p. 203.

TREMBLES. A disease of cattle that can cause " milk-sickness " (p. 738) in man in U.S.A.

TRENDS IN DAIRY TECHNOLOGY. In some respects the dairy industry is backward compared with other industries but during the last 20 years and especially in the last 5 years there has been a marked advance technologically in some directions especially (i) instrumentation and devising of fool-proof controls ; (ii) use of stainless steels and non-corrodible metals ; (iii) new rapid methods for pasteurising, buttermaking, etc. ; (iv) boiler control, efficiency, and economy ; (v) improved laboratory control. *See* Butter ; Cheese ; Condensed milk ; Ice cream ; Milk powder ; Milking machines ; Pasteurisation ; Transport.

Refs.: Cronshaw ; Cuttell ; Enock ; Farrall ; Hill ; Rogers.

TRIGLYCERIDES. Fats are chiefly composed of esters of glycerol and fatty acids. As glycerol has three alcoholic or —OH groups, the molecule can combine with three molecules of a monobasic fatty acid, such as stearic, to form a triglyceride. If different fatty acids are linked with one molecule of glycerol, the ester is a *mixed glyceride*. *See* Fats ; Fatty acids.

TROLLEY, CAN. A device for lifting milk cans. *See* Fig. Tc 1.

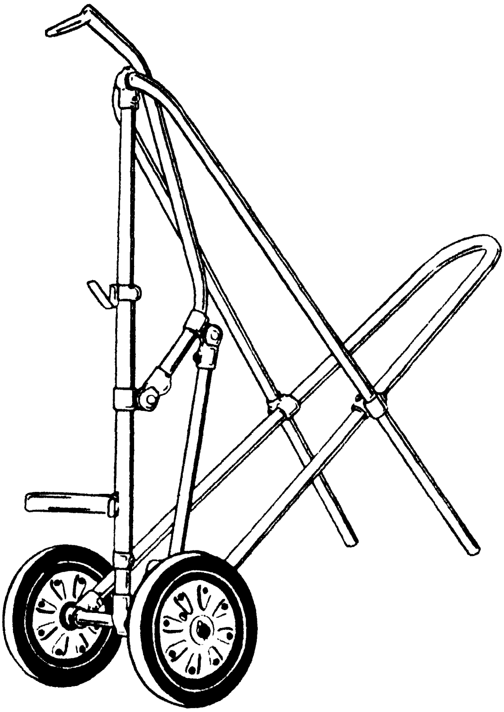
TRIMETHYLAMINE. This amine $N(CH_3)_3$ is responsible for the fishy flavour in butter and other dairy products and originates from the choline of lecithin (p. 601). *See* Fishiness.

TROMMSDORF METHOD. A method for estimating the *volume* of body-cells in milk. Ten ml. is centrifuged in a special tube with a calibrated capillary bore at the bottom and the deposit read off in the usual way.

TROPICAL DAIRYING.

Refs.: Wright (1952), *JSDT*, **5**, 149; Feunteun (1949), *IDC*, **1**, 609.

TRYPSIN. The main proteolytic enzyme of the pancreatic secretion active in weakly alkaline solution. *See* Digestion; Enzymes.



[*By courtesy of Gascoignes (Reading) Ltd.*

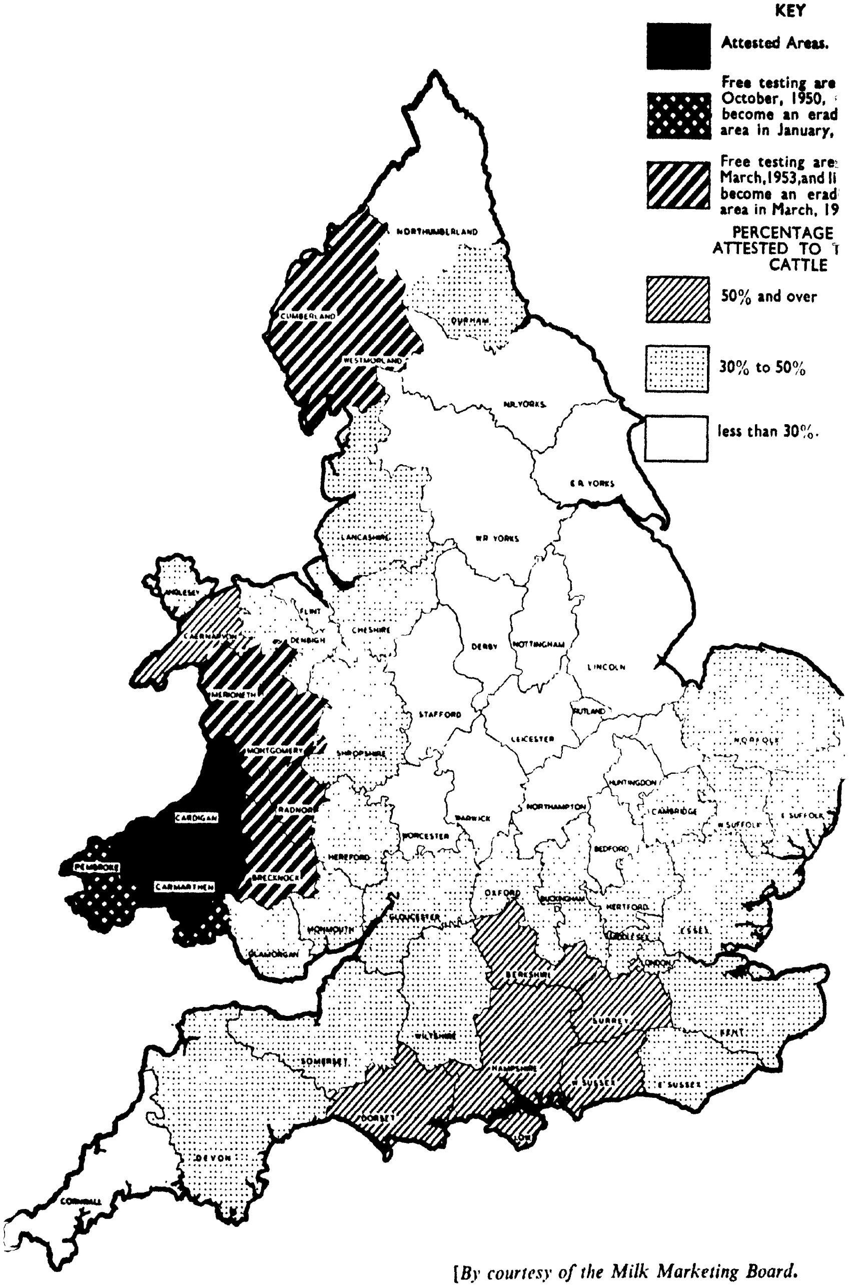
FIG. Tc 1.—*Milk can lift-trolley.*

TUBERCLE BACILLUS. Three main variants, human, bovine, and avian, of *Mycobacterium tuberculosis* are known. *See* Classification; Diseases; Pasteurisation; Tuberculosis,

Refs.: Soltys (1952), *Tubercle Bacillus;* Frimodt-Möller (1939), *Dissociation of Tubercle Bacilli*, London; Gaiger and Davies; Miller; Wilson and Miles; Wilson.

TUBERCULIN, TUBERCULIN TEST. Tubercle bacilli contain lipoids, polysaccharides, and proteins which constitute the antigenic structure of the organism. One of the proteins appears to be the active principle of *tuberculin* which is the extract used for the *tuberculin test*. This is the official test in this and other countries for the presence of tubercle bacilli in animals. The original tuberculin (Koch's " old tuberculin " or O.T.) was obtained by culture in glycerol broth but a synthetic medium is now used and the tuberculin protein is precipitated and purified to give " purified protein derivative " or P.P.D.

Three forms of the tuberculin test have been evolved—the ophthalmic, the subcutaneous and the intradermal. The first is least reliable and has been discarded, and the other two are about equally reliable. In the subcutaneous, from 2 to 5 ml. of a tenth dilution of O.T. may be injected and the temperature reaction observed. The intradermal test is made by injecting P.P.D. into the caudal



[*By courtesy of the Milk Marketing Board.*

FIG. Tu 1.—*Progress of eradication of bovine tuberculosis in England and Wales. When all cattle in an area are free from tuberculosis either as a result of progress in the voluntary scheme or of compulsory eradication the area may be declared an attested area.*

(below the tail) folds of skin or into the neck. The official Ministry of Agriculture test requires 0·15 g. of mammalian P.P.D. and 0·04 g. of avian P.P.D. to be injected into the middle third of one side of the neck, the avian about 4 in. below the crest of the neck and the mammalian about 5 in. below the avian injection. The thickness of a fold of skin is measured by calipers before the injection and at intervals of 48, 72 and 96 hr. Official testing requires the injection of a second dose after 48 hr. but the value of this is controversial (*see* Francis). An increase of 5 mm. is regarded as a positive reaction, 4 mm. being regarded as doubtful. The intradermal test has been preferred as it involves less labour than the subcutaneous and is less sensitive to " doping ". Usually an animal does not react to the test until 20 to 30 days after infection. Severely affected animals may not react to the test but over all about 95 per cent. of tuberculous animals can be detected by this test when used by an experienced worker, and with the proper understanding and precautions necessary with all biological tests. There is some suggestion that the test is less reliable with calves and young animals. *See* Tuberculin-tested milk ; Tuberculosis.

Refs.: Francis; Gaiger and Davies.

TUBERCULIN-TESTED MILK. Milk which is derived solely from a herd of tuberculin-tested cows under licence and kept pure and unmixed with other non-tuberculin-tested milk. If bottled on the farm it can be sold as " Farm-bottled " or, more strictly, " Tuberculin-tested (Farm-bottled) milk ". *See* Legal aspects ; Milk (Special Designations) Order ; Tuberculin test.

Refs.: Harvey and Hill ; Swift.

TUBERCULOSIS, BOVINE. A common disease of cattle and due to the bovine variant of *Myco. tuberculosis*, rarely the avian. It is more common in the North and the prevalence increases with the age of the cattle (Table Tu 1).

TABLE Tu I

Age (years)	*Percentage infected*
0 to 1	3
1 to 2	13
2 to 3	24
3 to 5	24
5 to 9	49
9 to 13	76

In cattle the lungs and pleura are chiefly affected and only rarely is the udder invaded. It is important to realise that although 35 per cent. of our dairy cattle may be infected (*i.e.* react to the tuberculin test) only about 0·4 per cent. are actively excreting the organisms in their milk. However, the diseased animals can discharge the germs by coughing and in their faeces. Only a minor proportion of animals develop visible symptoms of the disease although, of course, the infection once established, can " flare up " at any time. *See* Diseases.

Refs.: Wilson ; Francis ; M.R.C. (1933), " Tuberculous Infection in Milk ", H.M.S.O. ; Wilson *et al.* (1952), *Non-pulmonary Tuberculosis of Bovine Origin in Gt. Brit. and N. Ireland*, London; Davis (1953), *DI*, **18**, 210 (TB in types of milk); Bibby (Sect. IV) (historical).

TUBERCULOSIS, HUMAN. The disease caused by the human variant is, for all practical purposes, a distinct disease. This organism is more robust than the bovine and there is no connection between them in the sense that one can be converted into the other. Human tuberculosis is a disease of adults affecting chiefly the lungs, whereas the bovine type occurs in children and affects chiefly the joints and glands.

Refs.: Wilson and Miles ; Wilson ; M.R.C. (1942), " Report of the Committee on Tuberculosis in Wartime ", H.M.S.O. ; Savage (1929), *The Prevention of Human Tuberculosis of Bovine Origin*, London.

TURBIDITY TEST. *See* Sterilised milk.

TWORT-D'HERELLE PHENOMENON. A synonym for bacteriophage or " phage " *See* Starters.

TYPHOID FEVER. Enteric fever is caused by *B. typhosus* or *Eberthella typhosa.* *See* Classification ; Diseases.

Ref. : Wilson and Miles.

U

UGANDA.

Ref.: Tothill (1940), *Agriculture in Uganda*, London.

ULTRASONICS. *See* Pasteurisation, alternatives to.

ULTRA-VIOLET LIGHT, UV. That portion of the spectrum just shorter in wave-length than violet light. *See* Irradiation.

It has poor penetrating power, being easily absorbed by the atmosphere and thin layers of glass. It has appreciable bactericidal powers due to its effecting a change in bacterial protein. It produces hydrogen peroxide and ozone but these substances are not reponsible for the bactericidal power, at least not for the major part. *See* Disinfection; Irradiation; Pasteurisation, alternatives to; Sterilisation.

Refs.: Buchanan and Fulmer; McCulloch; Wilson and Miles; B.I.O.S. Final Report No. 770 (1946); Mattick (1934), *MI*, April, p. 34; Burton (1949), *JSDT*, **2**, 75; Voogd and Daams (1952), *LP*, **1**, 364.

UNCLEAN FLAVOUR. A characteristic flavour of milk and other dairy products. It may be produced by *S. lutea*, as for example when pasteurised milk is held in inadequately cleaned bottles. *Pseudomonas* and similar proteolytic and lipolytic types may also produce this taint. *See* Flavours.

UNDULANT FEVER. A characteristic infection caused by *Brucella abortus* and sometimes by *Br. melitensis* and *Br. suis* in this country. The first is responsible for contagious abortion (p. 293) in cattle; the second is associated with goats and the third with pigs. The three types are virtually identical.

The drinking of raw milk infected with *Br. abortus* can cause undulant fever and about 500 cases are known to occur annually. It is probable that many more really occur but are not diagnosed as such by general practitioners. *See* Diseases.

Refs.: Wilson and Miles; Wilson.

UNITED STATES OF AMERICA. *See* America.

UNITS. *See* Weights and measures.

UNSATISFACTORY PRODUCERS. From the hygienic aspect and the buyer's point of view from 5 to 10 per cent. of milk producers in this country are unsatisfactory in that their milk is of poor keeping quality. *See* Bacteriological grading of milk; Clean milk production; Farm advisory work; National Milk Testing Scheme; Quality payment.

UPERISATION. A new Swiss method of heat-treating or sterilising milk in which steam is injected under pressure to heat the milk to *c.* 150° C. The added water is then removed by evaporation under vacuum. Uperised milk reacts positively to the turbidity test (p. 1043) and phosphatase is reactivated on storage. The degree of destruction of vitamins appears to be about the same as that in pasteurised milk.

A similar method has also been developed in France. *See* Pasteurisation; Sterilised milk.

Refs.: Anon. (1953), *DM*, **74**, 1178; Fuchs (1953), *Mitt. Lebensm. Hyg.*, **44**, 162; Lang (1953), *DI*, **18**, 678; Mohler (1952), *Chimia*, **6**, 212.

URDA. A gassy alcoholic fermented whey from sheep's milk similar to skuta.

UREA. $CO(NH_2)_2$ the form in which waste nitrogen is excreted by many mammals. It can be used as a protein replacement for ruminants (Reid (1953) *JDS*, **36**, 955). *See* Feeding.

UTENSILS. A general term for plant, etc., used for milk on dairy farms. They comprise pails or buckets, churns, coolers, etc.

Construction. Stainless steel is best but rare on farms. Tinned steel is satisfactory but tinned copper and galvanised iron should not be used. Aluminium alloy might well be developed for farm utensils.

Cleaning. It is universally accepted that poor keeping quality in milk is due to dirty utensils and lack of cooling. Utensils should be rinsed immediately after use, cleaned with a suitable detergent and sterilised by steam or chlorine, the last preferably just before use. *See* Churns, dirty, effect on milk ; Cleaning and sterilising ; Clean milk production ; Detergents.

UTILISATION OF MILK. The term " utilisation " takes into consideration not only how the milk production of a country is disposed of, *i.e.* how much is consumed liquid and how much is converted into cheese, butter, etc., but also how the milk and milk products are distributed to the population.

The economic basis of the milk industry has been revolutionised during the last 15 years and the chief reasons for this have been (i) the establishment of the Milk Marketing Board ; (ii) the introduction of free or cheap milk for the priority classes ; (iii) the war and subsequent world food shortage. At the present time production has again caught up with demand, but in the thirties production in summer greatly exceeded the liquid demand which resulted in low prices for manufacturing milk and frequent waste of skim milk and whey because the price of the dried product did not justify the cost of drying. The disposal of milk in England and Wales for 1938 is given in Table U I and for Great Britain in 1938-39 in Tables U II and III.

TABLE U I—MILK UTILISATION IN ENGLAND AND WALES, 1938

	Gal.	
Wholesale contract	621,398,621	
Producer-retailers	136,000,000	
Total liquid	757,398,621	
Sold for manufacture	295,895,002	(= 93 per cent. of manufacture and 27 per cent. of total)
Farmhouse cheesemaking	23,902,998	(= 7 per cent. of manufacture and 2 per cent. of total)
Total gallonage	1,077,196,621	

UTILISATION OF MANUFACTURING MILK

	000 *Gal.*	%	*Output (Cwt.)*
Butter	84,198	28	300,700
Cheese	58,572	20	522,100
Condensed milk	68,301	23	2,439,300
Condensed milk (export)	8,863	3	
Milk powder	14,284	5	168,000
Fresh cream	47,283	16	305,100
Tinned cream	8,968	3	124,600
Other products	5,416	2	

The world war naturally had its repercussions on the manner of utilising the country's milk. The chief changes were the considerable fall in manufacture (which virtually ceased in winter) and the increase in liquid consumption. Milk became a No. 1 priority and the greatest effort was made to provide the priority

UTILISATION OF MILK

TABLE U II—Utilisation of Milk in Great Britain

Oct. 1938 to Sept. 1939 (million gal.)

(*after Capstick*)

Month	*Production*	*Liquid*	*Manufacture*	%		
				Monthly production (of total)	*Liquid*	*Manufacture*
Oct. 1938 . . .	97·6	72·5	25·1	7·8	74	26
Nov.	88·3	70·8	17·5	7·0	80	20
Dec.	86·5	71·5	15·0	7·0	83	17
Jan. 1939 . . .	87·9	71·8	16·1	7·0	82	18
Feb.	83·8	67·1	16·7	6·7	80	20
Mar.	97·8	73·5	24·3	7·8	75	25
Oct. to Mar. . .	541·9	427·2	114·6	43·3	79	21
April . . .	104·7	70·5	34·3	8·4	67	33
May	126·5	74·3	52·2	10·1	59	41
June	126·3	72·8	53·5	10·1	58	42
July	123·8	73·4	50·4	9·8	59	41
Aug.	119·8	70·8	49·0	9·6	59	41
Sept.	109·8	66·3	43·6	8·7	60	40
April to Sept. . .	711·0	428·1	282·9	56·7	60	40
Total for year .	1252·9	855·3	397·5	35·0	68	32

TABLE U III

Manufacture of Milk Products in Great Britain

Oct. 1938 to Sept. 1939 (million gal.)

(*after Capstick*)

Product	*Winter half year*	*Summer half year*	*Total*	*Summer-winter ratio*	*% of total*
Factory cheese . .	21·4	51·5	72·9	2·4	18·3
Farmhouse cheese . .	5·6	19·8	25·4	3·5	6·4
Soft cheese . . .	0·4	0·6	1·0	1·5	0·3
Total cheese . . .	27·4	71·9	99·3	2·6	25·0
Butter	25·9	87·2	113·1	3·4	28·5
Condensed and evaporated milk	24·8	66·6	91·4	2·7	23·0
Milk powder . .	4·7	12·9	17·6	2·7	4·4
Fresh cream . . .	25·3	34·1	59·4	1·3	15·0
Sterilised cream . .	4·7	7·5	12·2	1·6	3·1
Ice cream . . .	0·1	0·8	0·9	8·0	0·2
Other products . .	1·7	1·8	3·5	1·1	0·8
Total . . .	114·6	282·8	397·4	2·5	100·0

classes with that amount of milk which the nutritional experts decided was necessary for proper sustenance. It is of interest to note the changes in the allocations for the various types of manufacture. Cheese was halved, butter fell to almost a fifth, condensed milk to less than half, milk powder more than doubled, and fresh and sterilised cream and ice cream disappeared. The analogous figures for 1944-45 are given in Tables U IV and V.

TABLE U IV—UTILISATION OF MILK IN GREAT BRITAIN

Oct. 1944 to Sept. 1945 (million gal.)

(*after Capstick*)

Month	*Production*	*Liquid*	*Manufacture*	%		
				Monthly production (of total)	*Liquid*	*Manufacture*
Oct. 1944	100·0	99·4	0·6	7·4	99	1
Nov.	92·2	91·6	0·6	6·9	99	1
Dec.	95·5	91·7	3·8	7·1	96	4
Jan. 1945	97·9	94·1	3·9	7·3	96	4
Feb.	93·2	86·6	6·6	6·9	93	7
Mar.	111·3	99·0	12·4	8·3	89	11
Oct. to Mar.	590·2	562·3	27·9	43·9	95	5
Apr. 1945	124·8	100·5	24·3	9·3	81	19
May	148·4	109·3	39·1	11·0	74	26
June	138·2	108·6	29·6	10·3	79	21
July	126·8	107·8	19·0	9·4	85	15
Aug.	115·0	102·0	13·0	8·6	89	11
Sept.	101·1	99·5	1·6	7·5	98	2
Apr. to Sept.	754·2	627·7	126·6	56·1	83	17
Total	1344·5	1190·0	154·5	—	89	11

TABLE U V

MANUFACTURE OF MILK PRODUCTS IN GREAT BRITAIN

Oct. 1944 to Sept. 1945 (million gal.)

(*after Capstick*)

Product	*Winter half year*	*Summer half year*	*Total*	*Summer-winter ratio*	*% of total*
Factory cheese	4·5	39·6	44·1	8·8	28·6
Farmhouse cheese	—	5·0	5·0	—	3·2
Total cheese	4·5	44·6	49·1	10·0	31·8
Butter	3·2	21·1	24·3	6·6	15·7
Condensed milk	7·5	30·6	38·1	4·1	24·7
Milk powder	11·9	28·9	40·8	2·4	26·4
Other products	0·8	1·3	2·1	1·6	1·4
Total	27·9	126·5	154·4	4·5	—

UTILISATION OF MILK

The consumption of milk by the priority classes in Oct. 1946 is given in Table U VI.

TABLE U VI

Class	*Allocation*	*Consumption (weekly)* (gal.)
Children under 5	7 pints	6,382,000
Children 5 to 18	3½ pints	
Expectant mothers	9 pints	574,000
Mothers with children under 1 year	7 pints	342,000
Invalids		1,461,000
School milk		1,192,000
Hospitals, etc.		825,000
Total		10,776,000

The proportions of milk manufactured in the last few years are given in Table U VII (U.K.) and Table U VIII (Gt. Britain).

TABLE U VII

(*millions of gal.*)

Year	*Total gallonage*	*Gallonage sold for liquid consumption*	*Used for manufacture*	
			Gal.	%
1947	1450	1306	144	10
1948	1618	1419	199	12·2
1949	1735	1513	224	12·9
1950	1883	1557	326	17·3
1951	1790	1567	223	12·5

TABLE U VIII

(*millions of gal.*)

Year	*Total gallonage*	*Gallonage sold for liquid consumption*	*Used for manufacture*	
			Gal.	%
1947	1377	1263	114	8·2
1948	1540	373	167	10·8
1949	1649	1469	180	10·9
1950	1791	1515	276	15·4
1951	1706	1522	184	10·8

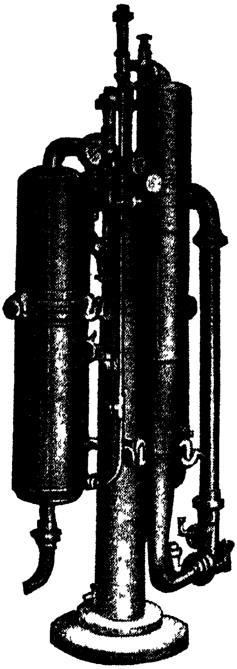
In 1952 82 per cent. of liquid milk in England and Wales and 73 per cent. in Scotland was pasteurised or sterilised.

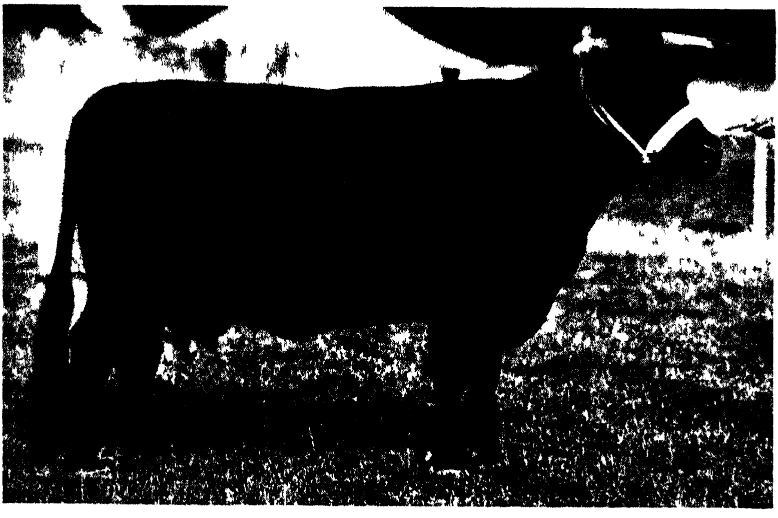
See Bacteriological grading ; Butter ; Cheese, p. 168 ; Condensed and evaporated milk ; Milk marketing ; Milk powder ; Nutritive values ; Quality payment.

Refs.: Capstick (1947), *JSDT*, **1**, 51 ; Green (1952), *JSDT*, **5**, 161 ; Comm. Econ. Ctte. (1953), *Dairy Produce*, H.M.S.O.

FIG. Va 1.

A Vacreator—supplied by Cherry-Burrell Limited. This Vacuum-Flash Pasteuriser is widely-used in Buttermaking, Cheese and Ice Cream Manufacture. Vacreated products have the advantage of considerably improved flavour, texture and keeping quality





[By courtesy of the Farmer and Stockbreeder

FIG Wa 1 —*Welsh Black.*

V

VACREATION, VACREATOR. A vacuum, odour-removing heat-treatment for cream which was developed in New Zealand and has been extensively adopted in that country, Australia and to some extent elsewhere. The most recent form is a triple treatment in which the cream is heated to *c.* 200° F. by steam and the volatile substances removed by the distillation of water vapour under reduced pressure. (Fig. Va 1.)

The principle has also been applied to milk for cheesemaking. *See* Butter; Cream.

Refs.: Wilster (1949), *IDC,* **3,** 70; Brown and Janzen, 471; Riddet *et al.* (1940), *N.Z. Dairy Res. Inst. Pub.*, No. 126; Fabricius and Bird (1940), *Res. Bull. Iowa Agric. Exp. Sta.*, **284,** 151; Brown (1940), *CDIC,* **19,** No. 3, 21; No. 9, 26; Robichaux (1944), *CDIC,* **23,** No. 11, 76 (cheese).

VACUUM LINES. *See* Milking machines.

VACUUM ROLLER DRIERS. *See* Milk powder.

VALENCY. The number of hydrogen or other monovalent atoms that one atom of an element can combine with, *e.g.*

	Valency		
Chlorine . . .	1	HCl	hydrochloric acid
Oxygen . . .	2	H_2O	water
Nitrogen . .	3	NH_3	ammonia
Carbon . .	4	CH_4	methane
		CO_2	carbon dioxide
Phosphorus . .	5	P_2O_5	phosphorus pentoxide

VALENTA TEST. This empirical test for the solubility of fats in acetic acid is made by heating under closely defined conditions a mixture of the fat and acetic acid and noting the temperature at which a turbidity is first apparent (*JSCI*, 1884, **3**, 643). The test has been placed on a more rigid basis by Fryer and Weston (*A*, 1918, **43,** 3) who have worked out corrections for the acidity of the oil, for the acetic acid in terms of pure almond oil, and a formula for expressing the results:

$$V = \text{temp. obtained with oil (corrected for acidity)} + (80 - \text{temp. obtained with standard oil, etc.})$$

$$\frac{V \times 10}{80} = \text{approx. } 4{\cdot}7 \text{ for butterfat; } 10 \text{ for almond oil; } 11 \text{ for tallow, lard; } 1{\cdot}5 \text{ for coconut oil.}$$

See Crismer test.

Ref.: Richmond.

VANASPATI. Vegetable ghee (p. 489).

VAPORISATION, LATENT HEAT OF. Heat is required to convert any liquid to vapour at the same temperature, and the amount of this heat is called the *latent heat of vaporisation.* *See* Refrigeration.

VAPOUR. The gaseous form of any substance which is liquid at ordinary temperatures.

VAPOUR PRESSURE. All liquids exert a vapour pressure, although this may be very small at room temperatures, as illustrated by the following figures (mm. mercury):

	− 20° *C.*	0° *C.*	20° *C.*	100° *C.*
Water	0·8 (ice)	4·6	17·5	760
Ethyl alcohol . .	2·5	12·2	43·9	1690
Acetic acid . . .	—	—	11·7	417
Ammonia (atmos.) . .	1·88	4·24	8·46	—
Carbon dioxide (atmos.) .	19·4	34·4	56·5	—
Mercury	—	—	0·0012	0·273

When the vapour pressure of a liquid (*e.g.* water) is allowed to attain equilibrium in contact with a gas (*e.g.* air) at any temperature, the space is said to be *saturated* or, in the case quoted, to have 100 per cent. humidity (p. 511).

The volume-pressure-temperature relationships of vapours are more complicated than those for gases, *e.g.*

$$v = \frac{RT}{p} \quad \text{(combination of Boyle's and Gay-Lussac's laws for gases)}$$

but
$$v = \frac{RT}{p} + f(T) + c \quad \text{(Callendar's equation for steam)}$$

where v = volume ; p = pressure ; R = gas constant ; T = absolute temperature ; c = constant ; f(T) is a function or expression of the absolute temperature.

All dairy products contain varying amounts of water. Some of this is free or unbound, some loosely bound, and some combined chemically as the water of crystallisation in blue vitriol or copper sulphate $CuSO_4 . 5H_2O$. When we determine the moisture content of a dairy product we heat it to 100° to 103° C. until no further loss in weight occurs ; unfortunately there is sometimes no clearly defined end-point as on cooling absorption of moisture may take place and the heating may result in some slight chemical decomposition. The tendency of the water to leave the product or the vapour pressure of water in the product is markedly influenced by the concentration of salt. For example, salt has a big effect on the hardness of cheese. Salts dissolved in water also affect the *osmotic pressure* so that there is a close relation between vapour pressure and osmotic pressure. From the practical point of view the most important aspects are : (i) effect on bacterial growth ; (ii) effect on enzymic activity ; (iii) effect on chemical activity of catalysts ; (iv) possible usefulness as a measure of water content.

(i) Low-moisture products such as milk powder and butter (fat phase) are highly resistant to bacterial growth. Soft cheese (over 55 per cent. water) rapidly deteriorate whereas ripened Cheddar and Parmesan keep well, because most types of bacteria die out.

(ii) and (iii) If the moisture content of milk powder rises above 3 per cent. there is always the possibility of deterioration due to oxidation and hydrolysis due to traces of metals and enzymes.

(iv) This aspect has received very little attention yet but Scott Blair *et al.* (*JDR*, 1941, **12**, 55), have shown that as little as 2 or 3 per cent. water can be detected in milk. *See* Cheese, p. 168 ; Stability.

VARIATION IN BACTERIA. Bacteria of any one type or species, and especially under varied conditions of environment, vary markedly in their morphology, biochemical reactions, vigour of growth, virulence, and in fact in nearly all their properties. *See* Classification.

Refs.: Wilson and Miles; Soc. Gen. Microb. (1953), *Adaptation in Micro-organisms*, London; Cold Spring Harbour Symposium (1946), *Heredity and Variation in Micro-organisms*, New York.

VARIATIONS IN COMPOSITION OF MILK. *See* Composition, factors affecting.

VATS. (i) **Farmhouse Cheesemaking.** These are usually circular, steam jacketed, made of tinned copper and hold 100 gal.

(ii) **Factory Cheesemaking.** These are usually rectangular, steam jacketed, made of tinned mild steel, and hold 250, 500, 750, or 1000 gal. The larger factories usually employ 1000 gal. vats but there are technical advantages in working with 500 gal. vats. (Fig. Ch I.) *See* Cheese.

(iii) The term is also applied to open tanks used for milk.

VEGETABLE FATS. These were at one time frequently used to adulterate butterfat and a number of methods have been proposed for their detection, mainly based on the characteristics of the fatty acids. Butterfat contains an appreciable proportion of volatile fatty acids but unfortunately coconut oil also contains these acids. The method usually employed to detect the presence of vegetable fats in butterfat depends on the fact that whereas the unsaponifiable (not broken down by boiling acids or alkalis) fraction of animal fat contains cholesterol (*c.* 10 per cent.), that of vegetable oils consists of phytosterol (30 to 50 per cent.). These sterols can be distinguished by the melting-points of their acetates (phytosterol 124° C., cholesterol 114° C.). Methods have been worked out by Hawley (1933, *A*, **58**, 529), and Stewart (1923, *A*, **48**, 155). The method can be used to detect the presence of vegetable fats in butterfat but not *vice versa*. *See* Fats; Fatty acids; Margarine.

Refs.: Williams, K. A.; Richmond.

VEGETATIVE CELL (OR FORM). In bacteriology this term refers to the non-spore-containing cells of spore-forming bacteria.

VENDÔME. *See* Cheese, p. 203.

VENDOR'S NAME. All carts, prams, etc., used for the retail sale of milk must display the vendor's name and address (Food and Drugs Act (1938)). *See* Legal aspects.

VENTILATION. Ventilation is essential in dairies not only because of the health of the worker but because dairy products will deteriorate unless temperature and humidity are maintained within certain limits. Thus high humidity may lead to mould growth, low to cracking of cheese. High temperatures may result in bacterial taints, greasiness in butter, " running " of cheese, etc. Low temperatures may lead to lack of ripening in cheese and " cold flavours ". *See* Cheese, p. 168.

VETERINARY SCIENCE. *See* Abortion; Diseases; Johne's disease; Mastitis; Tuberculosis.

Refs.: Miller; Gaiger and Davies (1946), *Veterinary Pathology and Bacteriology*, London; Thompson (rev. Duncan) (1935), *Elementary Veterinary Science for Agricultural Students, Farmers and Stock-keepers*, London.

VIETH'S RATIO. In normal milk there is a consistent relation between the lactose, protein, and ash. Vieth gave the ratio as 13 : 9 : 2 and Richmond has found almost identical values, 12·7 : 9·1 : 2. As with all data on composition, those for bulk milk give the closest agreement. Herd milks and especially single cow samples, may give widely divergent values. *See* Abnormal milk; Chloride-lactose ratio; Koestler number; Mastitis.

Refs.: Davies; Richmond.

VIRULENCE. This term is difficult to define precisely but it means broadly the ability of a micro-organism to invade and poison the tissues of an animal. The term can therefore be sub-divided into *invasive ability* and *toxin production*.

From the public health point of view, virulence is measured in terms of the proportion of fatal cases. In the laboratory, virulence can be more accurately measured in terms of dosage. *See* Toxins.

Ref.: Wilson and Miles.

VIRUSES, FILTERABLE VIRUSES. The group of viruses broadly includes all ultra-microscopic forms of life, *i.e.* those with a diameter of less than $0{\cdot}2\mu$ or 0·00002 cm. and which will pass through ordinary bacteria-retaining filters or candles but are unable to grow in cell-free media.

Viruses cause a number of well-known and characteristic diseases in animals and man. Viruses which are parasitic on bacteria are known as *bacteriophages* or *phages* (*see* Starters). The relative sizes of the more important viruses and phages are given in Table V I.

As far as is known, viruses are not of any special economic importance to the dairy industry apart from starter bacteriophages.

TABLE V I

Diameters of the More Important Viruses

(in $m\mu$. or 0·0000001 cm.)

B. coli, *Staphylococcus*, etc.	1000 to 1500
Bovine pleuro-pneumonia spheres	300
Bovine pleuro-pneumonia particles	150
Vaccinia (small pox)	150
Herpes	125
Rabies	125
Influenza B.	100
Staphylococcus phage	90
Swine influenza (American)	90
Fowl plague	75
Coli phage	40
Infectious anaemia of horses	35
Louping ill	25
Foot and mouth disease	10
Poliomyelitis (infantile paralysis)	10
Globulin molecule (serum)	6·3
Albumin molecule (serum)	5·6

See Starters.

Refs.: Wilson and Miles; Soc. Gen. Microb. (1952), *The Nature of Virus Multiplication*, London; Smith (1945), *Plant Viruses*, London; *Beyond the Microscope* (1943), London; Burnet (1946), *Virus as Organism*, Cambridge, Mass.

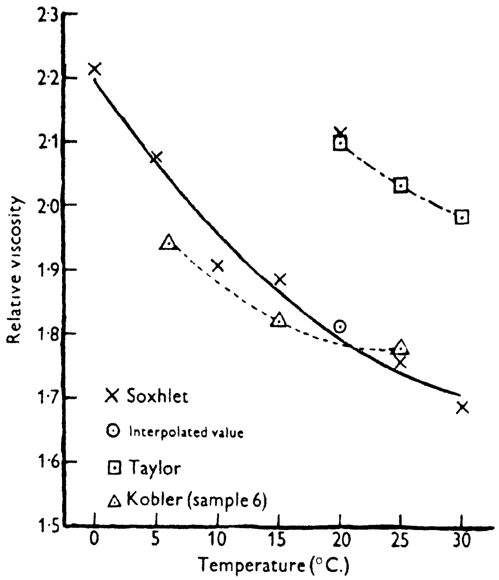
VISCOGEN. This thickening agent for cream is prepared by adding two parts of lime (CaO) in six parts water to five parts cane sugar in ten parts water. It may be used in the proportion of ½ to 1 oz. per gal. cream. Viscogen, like protective proteins, increases whipping properties and aggregation of the fat globules. Its use is, of course, illegal in cream for retail sale. *See* Ice cream; Thickening.

VISCOLISING. The treatment of homogenisation (p. 503) applied to cream.

VISCOSITY. *See* Rheology.

VISCOSITY OF CHEESE. *See* Rheology.

VISCOSITY OF MILK. Viscosity is a term used generally of properties concerned with the resistance to flow which obtains when a liquid in motion has different velocities at different points in a plane perpendicular to the flow. Quantitative measurements are expressed in terms of absolute or dynamic viscosity, kinematic viscosity and relative viscosity (*see* Rheological Measurements and Dimensions). The centimeter-gram-second unit (c.g.s.u.) of absolute viscosity, the poise, represents a force of 1 dyne per sq. centimetre when the velocity is changing at the rate of 1 centimeter per sec. per cm. distance across the flow. The ratio of the absolute viscosity to the density is the kinematic viscosity, for which the c.g.s.u. is the Stokes. The relative viscosity is obtained as the ratio of the absolute viscosity of the liquid to the absolute viscosity of water at the same temperature. An alternative use of the term relative viscosity which, however, has seldom occurred in the literature of dairy science is to denote, for example, the ratio of the viscosity of the cream to the viscosity of the fat-free serum. It is important therefore to know in which sense terms are being used.



[*By courtesy of the Journal of Dairy Research.*

FIG. V 1.—*Relations between temperature and the relative viscosity of whole milk.*

Practical interest has been largely concerned with the viscosities of cream, evaporated milk and skim milk, and comparatively little research work has been done on the rheological properties of whole milk. The viscous properties of milk are influenced by a number of factors, amongst which composition and temperature are probably the most important. Generally the viscosity appears to increase as the percentages of fat and of solids-not-fat increase, and to decrease as temperature increases. These relations have been expressed in various empirical formulae:

$$\text{s.n.f. per cent.} = \frac{\text{viscosity (relative)} - (0{\cdot}0665 \times \text{fat per cent.})}{0{\cdot}177} \qquad \text{(Taylor, 1913).}$$

$$s = \frac{7{\cdot}011 \log (\mathrm{T}/313) - \log\log (\nu + 0{\cdot}8) - 0{\cdot}8055}{0{\cdot}0708 \log (\mathrm{T}/313) - 0{\cdot}01990}.$$

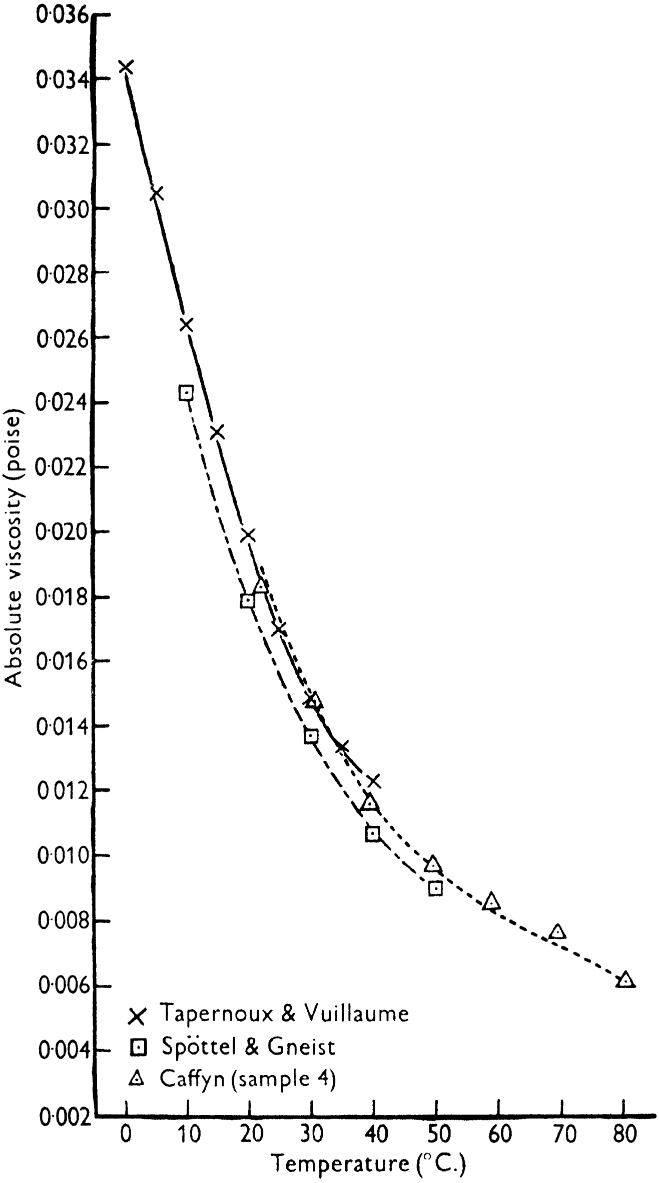
s = total solids per cent. by weight of 3 per cent. fat standardised milk.

ν = kinematic viscosity in centistokes.

T = absolute temperature. (Torssell *et al.*, 1949).

Changes with temperature alone (Figs. V 1 and V 2), depend on the milk used and the practical circumstances involved (Cox, 1952). A simple empirical formula has been proposed (*loc. cit.*) to connect the relative viscosity η'_θ at θ°C. with that, η'_{20}, at 20° C.:

$$\eta'_\theta - \eta_0 = a_1(\theta - 20) + a_2(\theta - 20)^2.$$



[*By courtesy of the Journal of Dairy Research.*

FIG. V 2.—*Relations between temperature and the absolute viscosity of whole milk.*

The results of experiments have been analysed to give in one case $a_1 = -4{\cdot}13 \times 10^{-3}, a_2 = 5{\cdot}36 \times 10^{-4}$, and in another case, $a_1 = -15{\cdot}10 \times 10^{-3}$, $a_2 = 3{\cdot}80 \times 10^{-4}$. Values obtained for the relative viscosity of milk at 20° C. have ranged from 1·70 to 2·10. For absolute viscosity, η, the corresponding formula is

$$\eta_\theta - \eta_{20} = b_1(\theta - 20) + b_2(\theta - 20)^2 + b_3(\theta - 20)^3.$$

The results of two experiments on untreated whole milk and one on homogenised milk have been examined and have given the following values for the coefficients b_1, b_2 and b_3:

	$b_1 \times 10^4$	$b_2 \times 10^6$	$b_3 \times 10^8$
Untreated whole milk .	− 5·919	8·666	9·899
	− 5·230	9·821	− 7·500
Homogenised milk .	− 5·895	10·089	− 6·886

The two observations on the absolute viscosity of milk at 20° C. gave values of 0·0199 poise and 0·0179 poise respectively, absolute viscosities of homogenised milk at 20° C. ranged from 0·0195 poise to 0·0206. *See also* Caffyn (1951), *JDR*, **18,** 95 (homogenised milk); Seidler and Elke (1949), *M*, **4,** 105 (factors in viscosity).

Refs.: Cox (1952), *JDR*, **19,** 72; Eilers *et al.* (skim milk); Taylor (1913), *J. Roy. Soc.*, N.S.W., **47,** 174; Torssell *et al.* (1949), *IDC*, **2,** 246.

VITAMINS. A vitamin may be defined as an accessory food factor, required in very small amounts for normal metabolism, but not synthesised in the body.

Up to the present, some 16 vitamins have been isolated and characterised, and a number of other possible vitamins have been postulated. The vitamins may be conveniently divided into the fat-soluble and the water-soluble vitamins.

Fat-soluble vitamins. This group includes vitamins A, D, E, and K; their formulae, properties and methods of estimation are collected in Table Vi I, and the biological potency, sources of, requirements for, and effects of deficiency of, these vitamins are given in Table Vi II. (Details of the vitamin content of dairy products will be found in the article on the Nutritive value of dairy products, p. 759).

Vitamin A occurs as such in fish-liver-oils and milk products, but herbivorous animals derive most of their vitamin A from its precursors, the carotenes, which occur in grass and green vegetables. β-carotene, the most important precursor, is converted to vitamin A in the intestinal wall.

Vitamin D_3 occurs in certain foodstuffs, but it is also formed by the action of ultra-violet light on 7-dehydrocholesterol in the skin, so that adequate exposure to sunlight ensures a supply of this vitamin. Vitamin D_2 (califerol) is prepared by the ultra-violet irradiation of ergosterol.

Water-soluble vitamins. This group includes vitamin C (ascorbic acid), and that large and ever-increasing group, the vitamins of the B complex. The formulae, properties, etc., of these vitamins are given in Tables Vi III and Vi IV. Many of the vitamins of the B complex are known to be required by the body as part of enzymes that are essential for the oxidation, hydrogenation and transformation of one substance to another. Thus vitamin B_1 (thiamine) is phosphorylated to give co-carboxylase; nicotinic acid forms part of co-enzymes I and II, and pantothenic acid part of co-enzyme A.

The water-soluble vitamins, and vitamin K, are synthesised by many different micro-organisms, including those that normally inhabit the intestinal tract of animals and birds, so that microbial synthesis contributes in varying degree to the host's requirements of these vitamins (Mitchell and Isbell, 1942).

In most animals the synthesis takes place in the large intestine, and as the products of synthesis are mainly within the bacterial cells which are largely excreted intact, the amount available to the host is small. But in the ruminant, where the

TABLE Vi 1

THE FORMULAE, PROPERTIES, AND METHODS OF ESTIMATION OF THE FAT-SOLUBLE VITAMINS

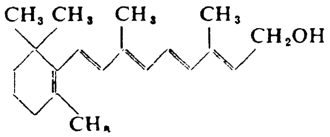
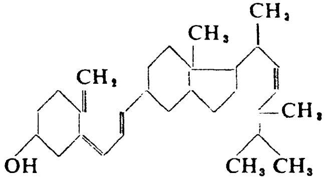
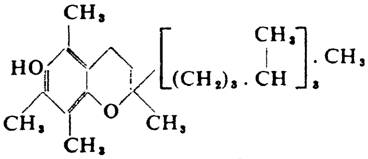
	Formula	*Historical*	*Properties*	*Estimation*
Vitamin A	 $CH_{20}H_{30}$	Recognised 1913; constitution established 1935; isolated pure 1937; synthesised 1947	Yellow crystals, m.p. 63° to 64° C. Soluble in organic solvents. U.V. absorption max. 325 mμ.	Biological: Rat growth Chemical: Carr-Price reaction Physical: U.V. absorption at 328 mμ.
Vitamin D_3 (natural vit. D)	 $C_{27}H_{44}O$ Vitamin D_2 (calciferol) $C_{28}H_{44}O$	Recognised 1934; constitution established 1935; isolated pure 1936; synthesised 1937	White crystals, m.p. 82° to 83° C. Soluble in fat solvents. U.V. absorption max. 265 mμ.	Biological: Cure of rickets in rats or chicks (vit. D_2 is not effective for poultry)
Vitamin E (α-tocopherol)	 CH₃ HO CH₃ (CH₂)₃ . CH 3 . CH₃ O CH₃ CH₃ CH₃ $CH_{29}H_{50}O_2$	Recognised 1922; isolated 1936; constitution established 1937; synthesised 1938	Yellow oil. Soluble in fat solvents. U.V. absorption max. 295 mμ. Acts as an anti-oxidant.	Biological: Fertility test in rats Chemical: reduction of ferric chloride giving red colour with αα-dipyridyl

TABLE Vi I (*contd.*)

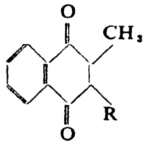
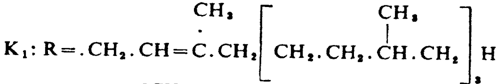
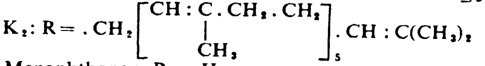
	Formula	*Historical*	*Properties*	*Estimation*
Vitamin K	  $K_1: R = .CH_2.CH{=}\overset{CH_3}{C}.CH_2\left[CH_2.CH_2.\overset{CH_3}{CH}.CH_2\right]_3 H$  $K_2: R = .CH_2\left[\begin{matrix}CH:C.CH_2.CH_2\\ \ \ CH_3\end{matrix}\right]_5 .CH:C(CH_3)_2$ Menaphthone: R = H $C_{31}H_{46}O_2$	Recognised 1934; isolated 1938; constitution established and synthesised 1939	K_1: yellow oil m.p. − 20° C. K_2: yellow crystals m.p. 53° to 54° C. Soluble in organic solvents. Stable to heat but not to alkali. U.V. absorption max. at 243, 248, 261 and 270 mμ. Menapthone: yellow crystals, m.p. 106° C. Soluble in organic solvents and slightly soluble in water. U.V. absorption max. 246 mμ.	Biological: Clotting time of chick blood

TABLE Vi II

THE BIOLOGICAL POTENCY, SOURCES OF, REQUIREMENTS FOR, AND EFFECTS OF DEFICIENCY OF, THE FAT-SOLUBLE VITAMINS

	Biological potency	*Best sources*	*Required by*	*Essential for*	*Effect of deficiency*	*Daily requirements of man*
Vitamin A	$3\frac{1}{3}$ million international units (i.u.)/g. I.u. of provitamin A is activity of 0·6 μg. of β-carotene	Fish liver oils, butter, cream, eggs, liver, green vegetables	Man, higher animals, birds	Growth. Maintenance of epithelial tissue. Retinal pigments and night vision	Poor growth in young. Lowered resistance to infection. Night blindness.	5000 i.u.
Vitamin D	40 million i.u./g.	Fish liver oils, butter, cream, eggs, liver	Man, higher animals, birds (birds can only use vit. D_3)	Ca and P metabolism	Rickets in children. Osteomalacia in adults	400 i.u.
Vitamin E	I.u. is the activity of 1 mg. of synthetic *dl*-α-tocopherol acetate	Wheat germ oil, green vegetables, eggs, liver	Man, higher animals and birds	Fertility and reproduction	Habitual abortion and loss of fertility. Muscular dystrophy	Not known
Vitamin K	Menaphthone (the synthetic vitamin) is 3·3 times as active as vitamin K_1	K_1: green vegetables K_2: micro-organisms of intestinal tract	Man, higher animals and birds	Prothrombin formation for blood-clotting	Prolonged clotting time of blood	Not known

TABLE Vi III

THE FORMULA, PROPERTIES AND METHODS OF ESTIMATION OF THE WATER-SOLUBLE VITAMINS

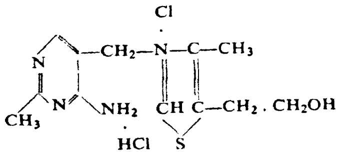
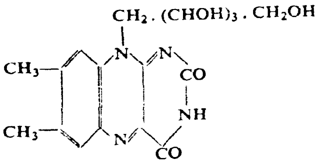
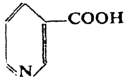
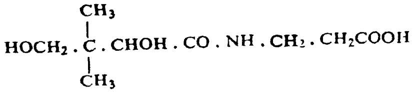
	Formula	*Historical*	*Properties*	*Estimation*
Vitamin B **Thiamine** (vitamin B_1 Aneurin)	 $C_{12}H_{17}ON_4SCl.HCl$	Recognised 1911; isolated pure 1926; constitution established and synthesised 1936	White crystals, m.p. 248° to 250° C. (decomp.). Soluble in water and alcohol. Insoluble in organic solvents. Stable in acid solution, but not in alkaline	Biological: rat growth; cure of bradycardia in rats Microbiological: growth of *Lactobacillus fermentum;* yeast fermentation Physical measurement of the fluorescence of thiochrome, produced by the oxidation of aneurin
Riboflavin (vitamin B_2, vitamin G)	 $C_{17}H_{20}O_5N_4$	Recognised 1917; isolated pure 1933; constitution established and synthesised 1936	Orange crystals, m.p. 282° C. (decomp.). Slightly soluble in water (12 mg. in 100 ml. at 27° C.) and in alcohol (4·5 mg. at 27° C.). Soluble in alkali but solutions deteriorate. Shows yellow-green fluorescence in solution	Biological: rat or chick growth Microbiological: growth of *Lactobacillus casei* Physical: measurement of fluorescence
Nicotinic acid (niacin, pellagra preventive factor)	 $C_6H_5O_2N$	Pellagra-preventive factor recognised 1926; shown to be nicotinamide 1937	White crystals, m.p. 235° to 236° C. Soluble in water and alcohol. U.V. absorption max. 385 mμ.	Biological: chick growth Microbiological: growth of *Lactobacillus arabinosus* Chemical: colour with cyanogen bromide and diazotised aromatic amines
Pantothenic acid	 $HOCH_2.\overset{CH_3}{\underset{CH_3}{C}}.CHOH.CO.NH.CH_2.CH_2COOH$ $C_9H_{17}O_5N$	Recognised 1933; isolated and constitution established 1938, synthesised 1940	Yellow oil. Soluble in water. The calcium salt is normally used. White powder, m.p. 198° to 200 °C.	Biological: chick growth Microbiological: growth of *Lactobacillus arabinosus*

TABLE Vi III (*contd.*)

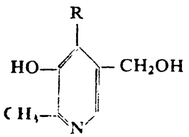
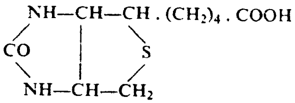
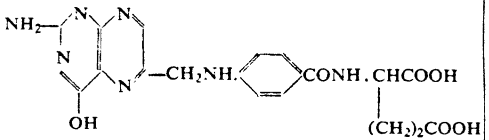
	Formula	*Historical*	*Properties*	*Estimation*
Vitamin B_6	 Pyridoxin R = . CH_2OH Pyridoxal R = . CHO Pyridoxamine R = . CH_2NH_2	Recognised 1934; isolated pure 1938; constitution established and synthesised 1939	Pyridoxin hydrochloride, m.p. 206° to 208° C. (decomp.); is soluble in water and alcohol	Biogical: rat growth Microbiological: growth of *Saccharomyces carlsbergensis*
Biotin (vitamin H)	 $C_{10}H_{16}O_3N_2S$	Recognised 1901; isolated pure 1935; constitution established 1942; synthesised 1943	White crystals, m.p. 230° to 232° C. Sparingly soluble in water and alcohol. Soluble in dilute sodium bicarbonate	Microbiological: growth of *Lactobacillus arabinosus*
Folic acid (vitamin B_c pteroylglutamic acid)	 $C_{17}H_{19}O_6N_7$	Recognised and isolated 1941; constitution established and synthesised 1946	Orange crystals. Slightly soluble in water. Soluble in dil. sodium bicarbonate	Biological: haemoglobin levels in chicks Microbiological: growth of *Lactobacillus casei*
Vitamin B_{12}	Not known Contains C H O N P Co	Recognised 1926 (liver factor); isolated 1948	Red crystals. Soluble in water	Biological: rat and chick growth Microbiological: growth of *Escherichia coli* or *Lactobacillus leichmannii*

TABLE Vi III (*contd.*)

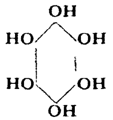
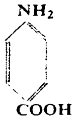
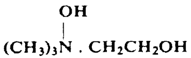
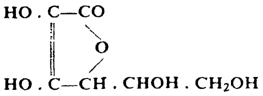
	Formula	*Historical*	*Properties*	*Estimation*
Inositol	 $C_6H_{12}O_6$	Recognised as a vitamin 1940	White crystals, m.p. 225° to 226° C. Soluble in water, insoluble in alcohol	Biological: cure of alopecia in mice Microbiological: yeast growth
p-Amino benzoic acid	 $C_7H_7O_2N$	Recognised as a vitamin 1940	White crystals, m.p. 186° to 187° C. Slightly soluble in water	Chemical: colour with *p*-dimethylamino-benzaldehyde Microbiological: growth of *Lactobacillus casei*
Choline	 $(CH_3)_3\overset{OH}{N} \cdot CH_2CH_2OH$ $C_5H_{15}O_2N$	Doubtful whether choline would be classed as a vitamin	Colourless liquid. Soluble in water and alcohol. Choline chloride usually used. White crystals, hygroscopic. Soluble in water	Chemical: precipitation as reineckate Microbiological: growth of *Neurospora crassa*
Vitamin C (Ascorbic acid)	 $C_6H_8O_6$	Recognised 1907; isolated 1928; constitution established and synthesised 1933	White crystals, m.p. 190° to 192° C. Soluble in water. Reducing agent	Chemical: titration with 2:6-dichlorophenol-indophenol Colour with 2:4-dinitrophenyl-hydrazine Biological: cure of scurvy in guinea pigs

TABLE Vi IV

THE BIOLOGICAL POTENCY, SOURCES OF, REQUIREMENTS FOR, AND EFFECTS OF DEFICIENCY OF, THE WATER-SOLUBLE VITAMINS

	Biological potency	*Best sources*	*Required by*	*Essential for*	*Effect of deficiency*	*Daily requirements of man*
Vitamin B Thiamine	333 international units (i.u.)/mg. 1 i.u. is activity of 3 μg. thiamine hydrochloride	Germ of cereals, yeast, meat, eggs	Almost all forms of life	Carbohydrate metabolism; nerve function; growth	Anorexia; loss in weight; beri-beri; bradycardia; polyneuritis	1·5 mg.
Riboflavin	No. i.u.'s dosed by weight	Milk, cheese, yeast, meat, eggs, liver,	Almost all forms of life	Cellular oxidation; carbohydrate metabolism; growth	Cheilosis; corneal lesions	1·8 mg.
Nicotinic acid	No i.u.'s dosed by weight	Meat, yeast, eggs, cheese, cereals	Almost all forms of life	Carbohydrate and protein metabolism	Dermatitis, diarrhoea and dementia (symptoms of pellagra); black tongue in dogs	15 mg.
Pantothenic acid	No i.u.'s dosed by weight	Milk, yeast, liver, eggs	Almost all forms of life	Carbohydrate metabolism	Dermatitis in chicks; grey hair and necrosis of adrenal cortex in rats	Not known
Pyridoxin	No i.u.'s dosed by weight	Liver, yeast, eggs, meat	Almost all forms of life	Fat and amino acid metabolism	Acrodynia in rats; poor growth; hypochromic anaemia in dogs and pigs	Not known

TABLE Vi IV (*contd.*)

	Biological potency	*Best sources*	*Required by*	*Essential for*	*Effect of deficiency*	*Daily requirements of man*
Biotin	No i.u.'s dosed by weight	Liver, egg yolk, milk, yeast	Almost all forms of life	Growth	Dermatitis and " Spectacle eye " in rats	2-10 μg.
Folic acid	No i.u.'s dosed by weight	Liver, yeast, green vegetables	Almost all forms of life	Bone marrow function. Red blood cell formation	Poor growth; anaemia	A few micrograms
Vitamin B_{12}	No i.u.'s dosed by weight	Liver	Almost all forms of life	Red blood cell formation	Pernicious anaemia	Probably a microgram or less
Inositol	No i.u.'s dosed by weight	Widely distributed	Almost all forms of life	Fat metabolism	Alopecia in rats	Not known
p-Amino benzoic acid	No i.u.'s dosed by weight	Widely distributed	Almost all forms of life	Unknown	Graying of fur in rats	Not known
Choline	No i.u.'s dosed by weight	Widely distributed	Almost all forms of life	Fat and protein metabolism	Fatty infiltration of liver	Not known
Vitamin C	20 i.u./mg. of pure *L*-ascorbic acid	Fresh fruits, milk	Man, guinea pigs and a few bacteria	Formation of intercellular material; healing of wounds; capillary resistance	Scurvy; gingivitis	25 mg.

microbial synthesis occurs in the rumen, which precedes the main digestive and absorptive tracts, the bacteria are subsequently broken down by digestive processes and the synthesised material becomes available to the host, so that the ruminant is independent of a dietary source of these vitamins (Kon and Porter, 1947-48). Thus the amounts of the vitamins of the B complex secreted into milk are not influenced by the content in the feed; this is in contrast to the dependence of the levels of vitamin A and carotene in milk on those in the ration (*see* p. 1055).

TABLE Vi V

THE FUNCTION AND SOURCE OF OTHER POSSIBLE VITAMINS

	Function	*Source*
Vitamins B_{10} and B_{11}	Chick growth and feathering	Liver
Anti-stiffness factor	Prevention of wrist stiffness in guinea pigs	Cream, sugar cane juice
Cow manure factor	Growth factor for chicks	Cow manure
Vitamin B_{13}	Growth factor	Distillers dried solubles
Vitamin B_{14}	Cell proliferating and tumor cell inhibiting factor	Urine
Vitamin L_1 and L_2	Lactation factors	L_1 in liver L_2 in yeast

Other possible vitamins. In addition to the vitamins which are identified, and which are listed in the tables, there are a number of postulated vitamins. Further research may show that some of these are identical or closely related to vitamins that have already been characterised, while others will probably take their place in the list of vitamins when more is known of their properties and functions. Examples of such possible vitamins are listed in Table Vi V.

Refs.: Barton-Wright (1952), *Practical Methods for the Microbiological Assay of the Vitamin B Complex and Essential Amino Acids*, London; Coates, Harrison and Kon (1951), *A*, **76**, 146 (assay of folic acid with chicks); Coates, Kon and Shepheard (1950), *BJN*, **4**, 203 (assay of nicotinic acid, riboflavin, pantothenic acid and pyridoxin with chicks); Coward (1947), *Bacteriological Standardisation of the Vitamins*, London; Gyorgy (1950), *Vitamin Methods*, N.Y.; Kon and Porter (1947-48), *Nutr. Abstr. and Rev.*, **17**, 31 (review article); Methods of Vitamin Assay (1947), N.Y.; Mitchell and Isbell (1942), Univ. Texas Publ. No. 4237, p. 125; Rosenberg (1942), *The Chemistry and Physiology of Vitamins*, N.Y.; Williams, Eakin, Beerstecher and Shive (1950), *The Biochemistry of B Vitamins*, N.Y.; Ford (1953), *BJNF*, 299 (microbiological assay of vitamin B_{12}).

VITAMINISED MILK. Milk is poorer in the fat-soluble vitamins, particularly D, in winter, so that addition of these vitamins is justifiable. Before the war such milks were on the market, either vitamin D being added artificially or the milk irradiated (*see* Irradiation).

Milk for powder for baby foods is now reinforced by addition of an emulsion of vitamin D. *See* Milk powder; Nutritive value; Quality payment; Vitamins.

Refs.: Adam (1950), *M*, **5**, 283; Schneider *et al.* (1950), *M*, **5**, 289; Scheer (1950), *M*, **5**, 292; Santer (1950), *M*, **5**, 296; Auhagen and Grab (1950), *M*, **5**, 299; Müller (1950), *M*, **5**, 304.

VIXEN MILK. *See* Mammals.

VOGES-PROSKAUER REACTION. The formation of a pink colour in sugar-containing broth by micro-organisms which produce acetoin or acetyl methyl carbinol (p. 5). *See* Classification; Coliforms.

VOLATILE (FATTY) ACIDS. Members of the aliphatic normal carboxylic (fatty) acids are volatile in steam up to myristic (C_{11}), the higher ones being *more* volatile due to their lower solubility in water. *See* Cheese ; Fatty acids ; Flavours.

Ref. : Bloor.

VOLATILISATION. The direct vaporisation of a solid without passing through the liquid form.

WAALS' RELATIONSHIP. The formula

$$\text{Total solids} = 0{\cdot}2285 \text{ sp. gr.} + 1{\cdot}3714 \text{ fat}$$

was obtained by Waals from a study of Friesian evening and morning milks (*WDC*, 1934, II, p. 217). Average values of 1·679 and 1·625 were found for the sp. gr. of the *dry* solids-not-fat material of morning and evening milk, the fat contents being 2·7 and 4·0. *See* Richmond's formula ; Total solids.

Ref. : Richmond.

WALES, DAIRYING IN. By common consent, Wales is regarded as a country pre-eminently suited for the production of livestock and livestock products—mainly in the form of store stock and milk. Several early historical records, some of which date back to the tenth century (The Laws of Hywel Dda), refer to the prominence of pastoral farming in the economy of the Welsh countryside.

At this period the people of Wales were a semi-Nomadic population, resulting partly from choice and partly from the pressure of invading peoples. Ancient laws relate how Welsh land occupiers moved to their plots on the hills for the summer months and returned to the valleys for the winter. These movements took place in early May and early November, respectively, and were such important dates in the Welshman's calendar as not to be altogether forgotten, even at the present time. It is thus understandable that the pastoral nature of Welsh farming arose, not only because of conditions relating to altitude, soil, and climate, but because it fitted in better with the roving habits of the people, than would arable farming. There was less difficulty with regard to the need for enclosing land, and livestock were more easily moved than arable crops could be. Cattle and sheep were the main types of livestock, although it is worthy of note that in the agricultural history of Wales in the Middle Ages, much more prominence is given to cattle than to sheep. This would seem contrary to what might be expected in what is a predominantly hilly or mountainous country. An instance of this emphasis on cattle is contained in the works of Giraldus Cambrensis, who states that in the early part of the fourteenth century, cattle were the wealth of the ancient Welsh, and that at that time, the Welsh peasants paid the rent to their landlords not in the form of money, but as so many head of cattle. These were what a noted Welsh historian has described as " the horned wealth ".

In considering thus the historical background of Welsh agriculture and the form which its development has taken, it must be recognised that there exists in the Principality a combination of circumstances which are favourable to the breeding, feeding, and general management of livestock. For milk production much emphasis has to be laid on such factors as climate, altitude, soil conditions and the nature of plant growth. Suitable farm buildings, availability and type of labour, as well as the general adaptability of the region to dairy work, are other features of no mean importance.

Elevation. It can be reasonably supposed that one of the main characteristics of the Welsh landscape is the dominance of uplands over lowlands; the rugged beauty of the mountains of North Wales has long been familiar to travellers and to a lesser extent the mountains and hills of the Cambrian range, which extend from the North into Central and South Wales.

The following figures show the division of the land of Wales on the basis of contour level.

Contour group *ft.*	*% of total*
0-500	41·0
500-1000	32·0
1000-1500	20·0
1500-2000	6·0
Over 2000	1·0

Thus, more than a quarter of the total land area of Wales lies above the 1000 ft. contour, and not much more than one-third of the whole is sufficiently low lying to be under the 500 ft. contour.

Soil. In many, if not most parts of Wales, the soil is thin and poor, with a noticeable deterioration taking place at increasing altitudes. It is, however, noteworthy that according to several authorities, there is in some of the Welsh river valleys soil of such quality as can produce some of the richest dairying pastures in the whole of Britain. This has been said of, for example, parts of the Vale of Towy in South Wales and the Vale of Clwyd in North Wales. However, the country as a whole, may be divided altitudinally into three regions, namely, the fertile lowlands, the undulating often hungry moorlands, and the bleak starved uplands. Typically, the lowlands are the dairying areas, the hill country and moorlands are (or should be) the stock-rearing areas, and the uplands are mainly devoted to sheep farming.

Climate. For successful dairy farming an essential pre-requisite is the production of ample quantities of suitable food for the dairy herd. The best and cheapest of these is grass, and good grazing is available only where climatic conditions are favourable. A good sward requires a moderate rainfall and temperature, a humid atmosphere and a fair proportion of sunshine so as to promote a long growing season. In all of these, Wales seems to be well blessed, but more especially in regard to rainfall. An examination of mean annual rainfall figures for four seasons in one of the Welsh counties over the years 1920-50 revealed that in most years they came within the comparatively high range of 50 to 60 in. for stations ranging between 50 and 250 ft. above sea level. Furthermore, in the case of a station 1650 ft. above sea level, the range was mainly between 90 in. and 130 in. over the same period, thus showing the relationship of altitude to rainfall, especially at high altitudes. Altogether the abundant rainfall, which is typical of Wales, means that a judicious combination of grassland and ley farming with milk production is indicated.

The Cattle of Wales. As already indicated, early historical records show that Wales has for a very long time been a country noted for its cattle. It has been said that the inhabitants had a natural aptitude for and interest in the tending of cattle. Whether the ancient Welsh were better than any other peoples in this respect may be debatable, but there can be no question that the main reason for the peoples' interest in their cattle was the fact that at certain periods their means of livelihood was almost entirely derived from this source.

There is a general concensus of opinion among historians that the native cattle of the British Isles were dark brown or black in colour. It is also probably true that the original cattle of these islands have persisted longest in the western parts. Support is lent to this contention by the observation which has been made, that even to the present day, the breeds of cattle which are predominantly black in colour are to be found in the western parts of these islands; mainly the areas associated with the Celtic peoples.

The native black cattle of Wales, which were the ancestors of those now known as the Welsh Blacks, are of great antiquity, and it is almost certain that in mediaeval times they were dominant over all other cattle in this area. There is evidence, however, that the colour and type characteristics did vary to some extent. For example, in the sixteenth and seventeenth centuries the North Wales specimens of the breed were more of the beef or draft type, whereas those in South Wales displayed more aptitude to dairying. This may account for the discrepancies between the opinion of some nineteenth century agricultural writers on the merits and demerits of the breed. Hassall, for instance, describes Welsh Blacks as being " unprofitable to the pail ", whereas C. S. Reid mentions cows of the " coal black Pembroke breed " as being " capital milkers producing 10 quarts per day or less of rich milk and thus yield 6 to 7 lb. of butter a week ".

This type difference gave rise to what were recognised as two breeds, namely, the " Anglesea " cattle which were concentrated on the western arm of North Wales and the " Castlemartins ", mostly inhabiting the western extremity of South Wales. It was not until 1874 that the first volume of the Welsh Black cattle herdbook was published, and this comprised a North Wales herdbook and a South Wales herdbook, run by two societies. Both societies were amalgamated in 1904, and since then, one herdbook has been used as a combined record for Welsh Blacks on both a herd and territory basis.

Present day specimens of the breed are typified in Fig. Wa 1. The potentialities of this hardy dual-purpose breed from the points of view of health, longevity, thriftiness and quality milk production, do not yet appear to be adequately realised.

The Cattle Trade from Wales in Bygone Days. There seems to be no record of when the cattle trade between Wales and England actually started. This is so, probably, because it developed from very small beginnings and without a realisation that in later centuries it was destined to become one of the main occupations of the Welsh peasantry. Not only did Welsh farmers very largely depend on this trade for their sustenance, but it came to provide occupations for many other members of the community including the dealers, drovers, blacksmiths, innkeepers and even bankers. Although it is not known exactly when this traffic and trade started, it is not difficult to realise why it started. It was chiefly because the rearing and tending of cattle was the people's main occupation and means of gaining a livelihood, so that a surplus had to be made available for disposal as store cattle. This surplus was an acceptable means of paying dues, and it was only natural that the cattle reared on the comparatively barren hills of Wales, should go to the rich pastures of England to be fattened and to make a substantial contribution to the supplies of roast beef for which England was justly famous in those days.

The Cattle Drovers. It appears that the Welsh word for drover, " porthmon ", became prominent in Welsh writings from about the fourteenth century. This may be taken as about the time when cattle droving acquired any considerable proportions, and from which it developed into a trade of such magnitude as to constitute what has been referred to as " an epoch in the agricultural history of Wales ". It was certainly a trade which flourished in the seventeenth, eighteenth and early nineteenth centuries, and probably would not have ceased at the present time were it not for the introduction of the cattle truck—firstly the rail truck and, more recently, road transport facilities.

The personnel concerned with the drover traffic comprised what were variously described as the dealers, master drovers, drovers and drivers. The dealers were mainly concerned with the buying and selling of the cattle, whereas the drovers and their assistants were responsible for all that was to be done in order to get the stock together into droves and delivered to their destination in England. Drovers as a class did not enjoy a very good reputation, either for humanity or for honest dealing, and it is not surprising, therefore, to find that in the sixteenth century all drovers had to be licenced by the Quarter Sessions for the county in which they had lived for at least three years previously, be married men, householders, and at least 30 years of age.

The distance which the droves were expected to cover extended to possibly 200 miles or more, and the rate of travel varied between 12 and 20 miles per day. The ability of cattle to stand up to these journeys was aided by the process of shoeing before embarking on the journey. This required each beast to be felled and securely fastened before the 2 shoes per foot were nailed on. The scene has been described as often reminiscent of the American rodeo shows. After such preparation for the journey, the drovers set off at dawn to avoid obstructions which would impede their progress, and travelled along tracks many of which ran quite a different course from the then existing turnpike roads. This was done, not only because of the less interrupted progress which it made possible, but also in order to avoid paying tolls at the many tollgates which had been set up on the main traffic arteries between the two countries. For example, there were said to have been 24 toll gates on the road from Aberystwyth to Rugby at the middle of the nineteenth century.

The numbers of cattle involved in this traffic may be gleaned from the fact that at the beginning of last century, it was estimated that between 30,000 and 40,000 Welsh " runts " were annually driven from Wales in the direction of London. Walter Davies mentions the annual cattle export of Anglesey alone as " about six thousand head ", all of which, incidentally, had to swim the Menai Straits in order to reach the mainland.

It will be obvious, therefore, that the drover was an important member of the community; it was to him that the Welsh peasant entrusted his wealth in the form of live stock. The custom in those days was to sell the cattle " on trust " and in anticipation that they would be paid for when the drovers returned from the English fairs. It is not surprising that the sixteenth century drovers were referred to as being comparable to the " ships of gold " which plied between America and Spain in the reign of Elizabeth I. Thus arose one of the main factors in Welsh economic history, namely, the introduction and development of the banking system. One of the earliest of these banks was that founded at Llandovery in Carmarthenshire in 1799, by a leading drover in the locality. The business was continued by the founder's descendants until well into the present century, and is to this day referred to by many local folk as the " Black Ox Bank ".

The Cattle of the Principality in Relation to the Development of Dairying. At about the time the curtain was drawn on the era of the cattle drover, the interests of the farming community, particularly in the southern half of Wales, began to be attracted to meeting the requirements of people in the then rapidly developing industrial era. Food being a primary essential, and recognising the important part which milk and its products play in it, meant that farmers began diverting attention to this potential market. Although the milk market in Wales was only a comparative trickle towards the end of the last century, it has developed to such an extent that milk production is now the main farming activity over large areas of the country, in the same way as store cattle rearing was, in the days of old. It is therefore to be expected that many changes affecting the cattle of the Principality have been occasioned by the increasing emphasis on milk production.

With regard to breeds, a traveller for any distance within the Principality cannot fail to notice the wide variety of breeds of cattle on the farms. It is also very noticeable that the Welsh Blacks, which had earlier dominated the scene, have by now been largely replaced by breeds of cattle which, until modern times, were completely foreign not only to Wales, but to Britain as a whole. As far as type is concerned, there is ample evidence that the beef breeds have receded to the background, and their place taken by the more specialised dairy types.

Another significant aspect of the influence of dairying on the cattle of Wales has been the way it has affected cattle numbers. The total number of cattle has not only progressively increased during recent years, but was at the close of the half century (1950) the highest on record, the numbers totalling just over one million head. On more detailed analysis the cattle population statistics for the predominantly dairying areas, reveal an important and rather disturbing feature. It is the fact that during the second quarter of the present century, the numerical increase has been very largely confined to the numbers of cows and heifers in milk or in calf, with until recently, a prolonged drop in the numbers of cattle two years old and under. These trends in relation to the cattle in Carmarthenshire, which is one of the most intensive dairying areas in Wales, are shown in Fig. Wa 2.

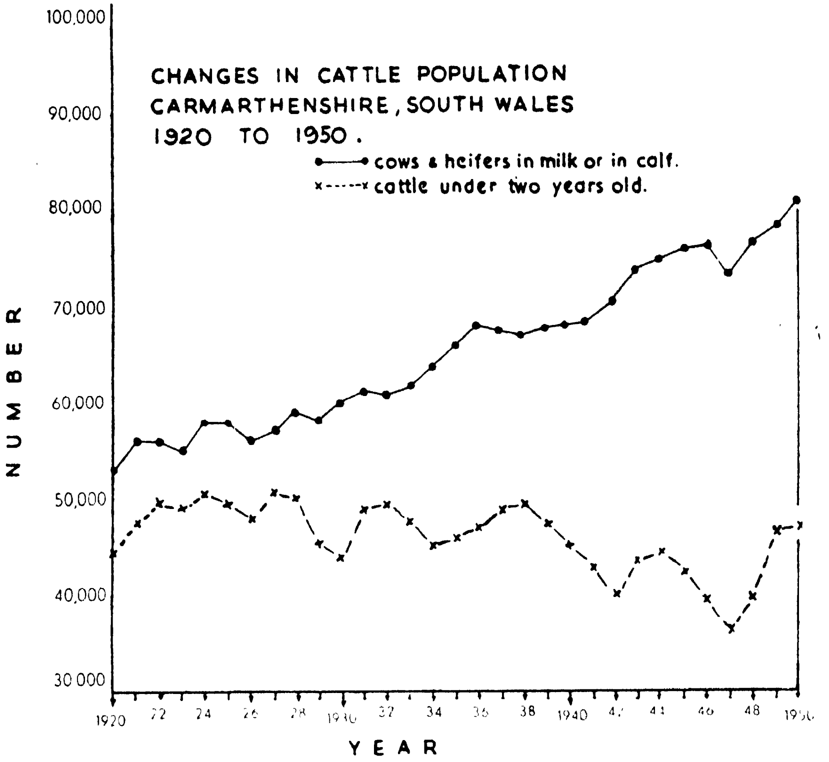


FIG. Wa 2.

The trends shown, which are quite obviously associated with the competition between " the milk churn " and the rearing of stock, bring to light a factor which may well have serious repercussions on herd maintenance in the Principality. Conditions which gave rise to the drover traffic proved the potentialities of Wales as a stock-rearing country, and may still provide stock breeders in the area with lessons on which they could profitably reflect.

From Farmhouse to Creamery. Although many of the details regarding early methods of producing and handling milk and its products have been lost in antiquity, it is obvious, when comparing them with modern methods, that fundamental changes have taken place. These apply both from the technical and from the economic standpoint, but it is somewhat surprising to find that most of the spectacular changes in the industry have taken place within the past three-quarters of a century. Farmhouse production has given place to the factory or creamery system, crude methods have been replaced by highly skilled scientifically controlled practices, and manpower has to a very large extent been replaced by a variety of machinery and mechanical appliances.

Bearing in mind what has already been stated regarding the annual export of cattle from Wales, it is reasonable to suppose that the quantities of milk and dairy products available at the time were not great and did not appear to contribute a major share to the income of the Welsh farmer. It is therefore surprising to find that in the sixteenth and seventeenth centuries butter and cheese in considerable quantities were actually being exported from parts of the Principality. Particulars concerning such consignments of dairy produce are contained in "The Welsh Port Books 1550-1603", which are some of the earliest records dealing with the commercial history of mediaeval Wales. Hassall also mentions that as late as the eighteenth century, butter was being exported from some of the South Wales ports. This trade provides a great contrast to that existing in the mid-twentieth century period when more than three-quarters of the quantities of these dairy products consumed in Wales are produced in other countries. However, it should be mentioned in this connection that in mediaeval times the population of the whole of Wales was estimated to be not more than 200,000, whereas the most recent census figures showed that there were, in the second quarter of the present century, over two-and-a-half million people in the Principality (Wales and Monmouthshire). This was a direct result of the development of the industrial era, which meant that it was no longer a population of country dwellers, but one in which a rapidly increasing proportion of the people went to live in towns and villages. It thus soon became obvious that the Welsh farmer's market for his produce came nearer home and, instead of supplying distant, and even overseas markets, there was a market in his own country, particularly among those engaged in non-agricultural industries. At this time it was customary for each farmer to store a season's production of butter and cheese until the Autumn, and then dispose of it in bulk to dairy produce merchants in the industrial areas, such as the mining valleys of South Wales.

The Establishment of Creameries and the Development of the Liquid Milk Trade. The commercial dairies of Wales, both large and small, owe their origin to the development of the industrial era, and it is therefore natural to find that the commercial side of the industry began its development along the fringe of the industrial areas of South Wales. This applied both to the handling and treatment of milk for liquid sale, as well as to the manufacture of dairy products in the form of butter and cheese. The butter factories of the Principality were originally butter-blending depots, to which supplies of unsalted butter were brought from farms in the vicinity, for blending and subsequent distribution in the mining valleys. Such, for example, was the origin of the Milk Marketing Board's Creamery, Pont Llanio in Cardiganshire, and the Towy Valley Dairy at St. Clears, Carmarthenshire. The latter, which was one of the first "butter factories" in Wales, was officially opened in June 1890. One of the earliest large-scale milk depots and cheese factories in Wales was at Laugharne, Carmarthenshire, and was established primarily to act as a supply depot for the retail milk trade in Cardiff. This dairy still survives, but has long since ceased to be used for its original purpose.

From these humble beginnings the area's large and prosperous dairy industry of the present day has progressively developed. With the progress of the century, there have been setbacks to contend with, particularly when the farmers' cooperative dairies became notorious for ending up in bankruptcy, about the time of the First World War, and the marketing difficulties which characterised the milk trade for a decade or so before the advent of the Milk Marketing Board. It was this Board that actually established the dairy industry in Wales, as elsewhere, on a sound footing, and since then progress has for the most part been uninterrupted.

The Milk Supplies from Welsh Farms. This aspect of dairying in Wales can conveniently be considered under two headings, namely: (*a*) the quantitative increase in milk sales; (*b*) the qualitative improvement as indicated by the increasing proportion of designated milk producers.

The pioneers of commercial dairying in Wales could have been forgiven for concluding that the milk production potential of the area was not great. Several reasons for such conclusions could be given, such as the high proportion of hill land and the inherently poor nature of much of the soil. These and other factors indicated a farming policy based on stock rearing, rather than milk selling.

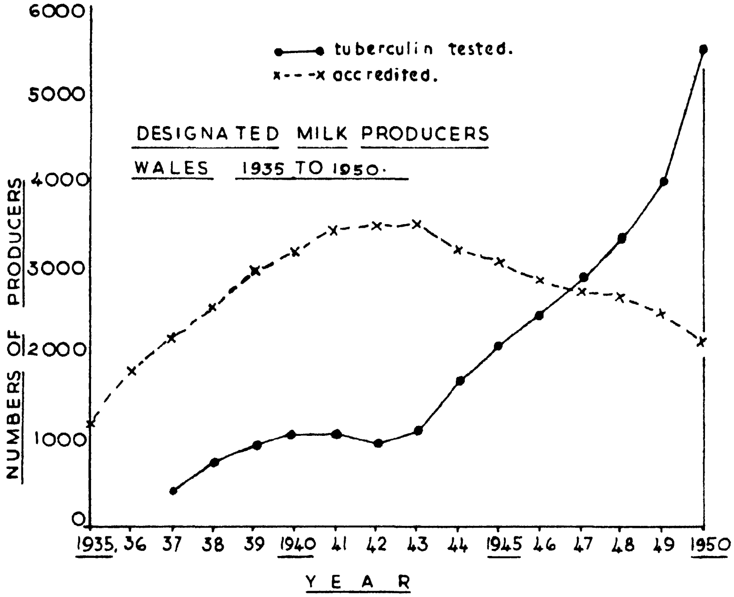


FIG. Wa 3.

However, the trend of events, being largely dictated by economic factors, has conclusively shown that Wales can and does make a substantial contribution to the nation's milk supply. The increasing extent of this contribution since the advent of the Milk Marketing Board, is shown in the following table.

MILK SALES OFF FARMS—WALES/ENGLAND AND WALES

(*Million gal.*)

Year	*Wales*	*England and Wales*
(up to 30 Sept.)		
1933-34	47	855
1938-39	81	1119
1945-46	120	1259
1949-50	167	1586

It will be seen from the figures given, that over the period 1933-50 the milk sales off the farms of Wales have increased to between three and four fold. Comparative figures for England and Wales show that the increase in milk output has been at a much slower rate and has, in fact, less than doubled during the same period.

In regard to quality also, there is evidence that the Welsh milk producers are conscious of the contribution which they should make to the general improvement of the safety and cleanliness of the nation's milk supply. The most noteworthy contribution in this respect, has been the progress made in the certification of tubercle-free herds under the Attested Herds Scheme. In that part of South-West Wales comprising the counties of Cardigan, Carmarthen and Pembroke, 61 per cent. of the total cattle in the area were attested at the end of the year 1950, and this has now become the first region in England and Wales where all the cattle are certified to be free from tuberculosis. Furthermore, the percentage of attested cattle to total cattle in Wales in June 1951 was 39·9 per cent. as against 21·5 per cent. in England.

The progress of the graded milk movement in Wales is shown in Fig. Wa 3.

Noteworthy features of this movement to up-grade milk supplies are the continued overall increase in the number of designated producers, the extent to which the production of Tuberculin-Tested milk has eclipsed the production of Accredited Milk and the recent steep rise in the production of Tuberculin Tested milk.

These achievements are all the more praiseworthy when it is realised that a very high proportion of Welsh farms are seriously handicapped in regard to many of the facilities which are recognised as being essential to the production of high grade milk. Among these may be mentioned unsuitable buildings, inadequate water supplies, and lack of electricity services. A recent detailed survey of facilities for milk production in a South-West Wales area covering six parishes, showed that only 28·5 per cent. of 523 farms had a piped water supply available for dairy use, and of the same number of farms, only 3·2 per cent. were provided with an electricity supply.

The Distribution and Utilisation of the Milk Output from Welsh Farms. It has been said that the principal export commodities of Wales are coal, milk and water. This statement at least serves to emphasise the fact that a large proportion of the milk sold off Welsh farms finds its market outside the Principality. In fact, the following figures issued by the Milk Marketing Board show that more than a third of the milk produced in Wales is utilised elsewhere.

Utilisation of Milk Sold from Welsh Farms in 1949-50

	%
Consumed in Wales	43
Sent to the London area	24
Sent out of Wales to other areas	11
Manufactured	22

When it is realised that the percentages given above, together amounted to no less than 167 million gal. in the year 1949-50, the magnitude of the task undertaken at commercial dairies in the area becomes apparent. Of these, there are a total of thirty creameries and dairies, each receiving a daily milk supply from over 100 suppliers. There are, in addition, a large number of dairies with lesser intakes. Of the larger commercial dairies in Wales, several have a peak daily intake in excess of 25,000 gal., while there are instances of plant at some of these dairies which have been used for condensing and for drying milk at the rate of millions of gallons per annum.

On this pinnacle of achievement, the dairy industry in Wales has passed into the second half of the twentieth century. It is quite obvious that the rate of development of the industry in the first half of the century cannot hope to be maintained during the second half. The tremendous possibilities of increased milk production that were open to the farmers of Wales in the past have been fully exploited. The emphasis henceforth must needs be on quality production and not quantity production. However, there are practical indications that in the movements towards the eradication of disease from dairy herds and in the production of high grade milk, Welsh farmers are active participants. What is likely to be of greater concern and a difficult problem to solve, is what seems to be the present over-emphasis on milk selling from the hills and upland farms generally. Their proper function is the rearing of store cattle as in the drover days of old, not perhaps for the fattening pastures of the English Midlands, but for the lowland dairy farms of Wales. In these matters, economics and price fixing play a leading part, but it is to be hoped that whatever may be the course of the " milky way " in the future, it will contribute towards ensuring and maintaining a proper balance between stock rearing and milk selling. Without this, the Principality of Wales cannot contribute in full measure to the maintenance of a healthy and prosperous agriculture.

WASHING POWDERS. *See* Detergents.

WASTAGE. Wastage is one of the most important factors in the dairy industry, but very clear thinking is essential in any attempt to assess wastage. If we consider wastage in broad terms as the difference between " milk in " and " milk out ", it will be evident that many factors can be contributory to the problem, *viz.* : (i) true wastage, *i.e.* milk lost by spillage, plant washing out, etc. ; (ii) errors in measurement ; (iii) apparent errors due to shrinkage or expansion when milk is measured by volume due to (*a*) temperature changes, (*b*) frothing, (*c*) Recknagel effect.

These factors do not affect the weight of milk and it is therefore fundamentally sounder to measure milk by weight wherever possible.

Maximum figures for true wastage under average conditions should be: (i) collecting and cooling, 0·2 per cent. ; (ii) pasteurising and bottling, 0·5 per cent.; (iii) retail distribution, 0·3 per cent.

A simple method of assessing true wastage is to estimate the milk in the effluent by a turbidity measurement. Either a drip feed sampling or sampling at frequent intervals should be made, as otherwise misleading results will be obtained. Matching may be carried out by making up known dilutions in a series of tubes or flasks, *e.g.* 0·1, 0·03, 0·01 per cent., etc., or by adding milk to a similar volume in a similar vessel until matching is obtained.

This method naturally cannot be used if the effluent contains other turbid matter. *See* Accuracy ; Costings ; Management of creameries, of pasteurising depots ; Richmond's formula ; Specific gravity.

Ref.: Rugaber (1953), *CDICJ*, **32,** 40.

WASTAGE IN DAIRY CATTLE.

Ref.: Phillips (1951), *JDR*, **18,** 1.

WATER. *See* Moisture.

WATER, ADDED, IN MILK. *See* Freezing-point test.

WATER GLOBULES IN BUTTER. *See* Butter.

WATER SOFTENING. *See* Cleaning and sterilising ; Detergents ; Water supplies.

WATER SUPPLIES FOR DAIRY PREMISES. An adequate supply of water has always been a necessity for the dairy farm. In earlier times, when the making of butter and cheese was essentially a farmhouse activity, supplies were needed for drinking water for the cattle, washing water for the butter churns, and such quantities as may have been used for rinsing churns and vats and washing the floors. Since then the character of the milk industry has changed completely. Demands of large urban populations have been met by large-scale transport and distribution of liquid milk and by development of large pasteurising depots and factories, where vast quantities of milk are treated by heat, bottled and sold as liquid milk, or manufactured into cheese, butter, condensed or dried milk, or casein. This change has resulted not only in an enormous increase in the quantity of water required but also in an increasing insistence on a high standard of quality.

It has been shown (*see* Taylor [1]) that when dry, a cow requires 6 to 8 gal. of drinking water a day and that when in milk it needs an average of 4 gal. of water in addition for every gal. of milk produced. Allowance must also be made for losses, including loss by evaporation from troughs, etc., which on an average day in summer (New Zealand) was estimated to be 1 gal. for every 85 sq. ft. of exposed water surface. The volume of cooling water required will depend on its temperature but as an example Taylor mentions that if, in warm weather, water with a temperature of 60° F. is used, about 6 gal. will be required to cool a gallon of cream to 65° F. and slightly more to cool a gallon of milk. The requirements for flushing out, washing and sterilising the milking plant and utensils in a dairy of average size were put at 80 gal. a day, which allowed for the use of 20 gal. of cold and 20 gal. of boiling water at each milking. On the basis of these figures, and after making an allowance for washing floors, etc., Taylor's estimate of 1200 gal. of water a day for a farm with 50 cows in full milk would appear to be a bare minimum, even supposing the cooling water could be used for other farm purposes. In addition to the *quantity* being sufficient it is essential that the *rate* at which water can be supplied to the cooler should be sufficiently fast, *e.g.* six to eight times as fast as the milk passing over it. Amounts needed for domestic purposes must, of course be included when computing the total requirements of the farm. In this country the average daily consumption per head is about 20 to 40 gal. and shows a tendency to rise.

As examples of the vast quantities of water required by dairy factories Taylor mentions that in two cheese factories where meters were installed it was found that an average of 3350 gal. of water were used for every ton of cheese made; one butter factory producing 3000 tons of butter a year used 50,000 gal. of water a day, and another factory, with a yearly production of 2500 tons, used 25,000 gal. a day; one large factory producing dried milk had a daily consumption of 200,000 gal. Among factors influencing consumption of water are the following: (i) Steam driven plant consumes more water than electrically driven plant. (ii) The lower the initial temperature of the water the less will be required for a given cooling effect. (iii) Methods of cooling differ in their efficiency. (iv) Depending on temperatures, water charges, pumping costs, and availability of supplies, it may be economical to install large storage tanks and to recirculate a large proportion of the water. It is usually necessary in this case, however, to include a cooling unit in the circuit. Thus, in one butter factory with peak requirements of 10,000 to 11,000 gal. of water an hr. for 10 hr. a day, the supply from the well gave only about 2500 gal. a day.

Water consumption in a modern dairy where raw milk is bottled or in a pasteurising depot is very high. Cold water is required for cooling either the fresh milk or the pasteurised milk, for rinsing bottles, churns, and other equipment, for flushing pipe lines and washing floors; hot water is used for washing bottles and for supplying heat to certain types of pasteurisers; steam is required for sterilising churns, bottles, milking pails, pipe-lines, etc.

That the keeping quality of milk depends in a large measure on delaying the growth of those micro-organisms which gain entrance to it, and that an abundant supply of water for cooling and for washing utensils is essential for the purpose, are now well recognised facts. That the chemical and bacterial quality should be above suspicion is no less true. Water which is corrosive, or which contains iron or manganese, for example, may play havoc with water pipes or dairy utensils and plant, or cause unsightly stains on equipment and floors; a supply which contains small quantities of heavy metals—especially copper, iron, or manganese—may convey traces to the milk through such routes as leaky coolers and so be responsible for tallowiness in milk, butter, or dried milk, or for a metallic and bitter flavour in milk or cheese ; water which is too hard leads to difficulty in cleaning utensils and to formation of a troublesome scale in boilers.

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[1] Taylor (1935), " Water Supplies of Farms and Dairy Factories in Hamilton Basin and Hauraki Lowland ", Department of Scientific and Industrial Research (N.Z.), *Bull.* No. 48.

It is a sound principle that a water supply likely to come into contact with any article of food should attain a bacteriological standard equal to that of drinking water. Considerations of public health alone justify insistence on this standard, for a supply which is suspect is a potential source of intestinal pathogens and may be responsible sooner or later for an outbreak of typhoid or paratyphoid fever. There are also, however, cogent economic reasons why the water should be bacteriologically pure. Coliform bacteria, for example, in addition to being a recognised index of faecal pollution in water, may themselves be responsible for a serious deterioration in the keeping quality of milk, for objectionable off-flavours in milk or butter, and for gassiness in cheese ; rancidity in dairy products, especially butter, may be caused by the lipolytic action of water-borne bacteria of the *Pseudomonas fluorescens* group ; the strains of streptococci and of coliform bacteria responsible for " ropiness " in milk have frequently been traced to the water supply.

It is important for these reasons that the farmer, the retail dairyman, the factory manager, and the student of dairying should understand the significance of " quality " in a water supply. Such understanding is most surely based on a knowledge of the sources from which supplies may be drawn, the routes by which pollution may gain entrance and the methods by which raw water may be rendered chemically satisfactory and bacteriologically safe.

SOURCES OF WATER. Average rainfall over Great Britain results in an annual precipitation of about 50 billion gal., equivalent to about 3000 gal. per person per day for a population of 45 millions. Making allowance for loss by evaporation Parker [1] estimates that about 60 per cent. of this amount finds its way into rivers, streams, and underground reservoirs.

The differences between the various sources of supply may be quickly understood by a glance at the diagram of a hypothetical geological section of the earth's crust (Fig. W 1). Part of the rain falling over the area flows as *surface water* into the river and the remainder percolates into the ground. Sub-soil water forming in an upper stratum may be collected by means of a *shallow well.* If, as in Fig. W 1, there is an impervious stratum overlying a porous one, rain may percolate through the outcrop of the latter and collect beneath the impervious rock. *Deep well* is a term usually applied to a well sunk through such an impervious rock to tap the water beneath. An *artesian well* is a deep well drilled at a low-lying point on the surface so that the " head " of subsurface water makes it rise

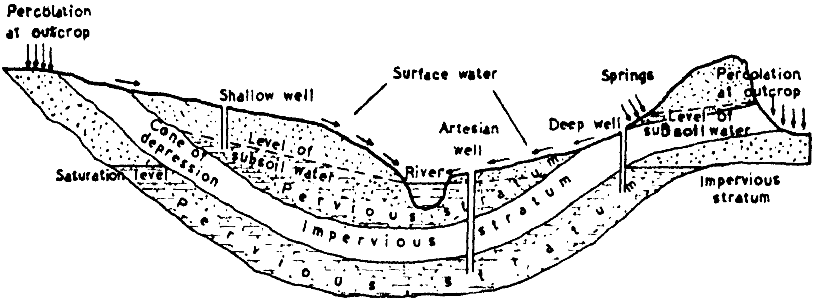

FIG. W 1.—*Geological section showing sources of water supply.* (*Adapted from Diagram by Adams.*[2])

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[1] Parker (Oct. 1942), "Treatment of Water for Domestic and Industrial Requirements. Some Problems and Methods ". *Trans. Inst. Civ. Eng.*, p. 365.

[2] Adams (1938), *Waterworks for Urban and Rural Districts*, London. Pitman.

in the well of its own accord, in some cases even above the surface of the ground. Rain permeating an upper stratum and meeting a sloping impervious layer, as shown in the formation on the right of Fig. W 1, tends to gravitate down the slope of this layer and reappear on the side of the hill as a *spring*.

Surface waters. Surface waters are usually divided into two categories. *Upland surface waters* are derived from surfaces of bare rocks (such as slate, limestone, and granite) or of uncultivated ground, from which they drain rapidly and frequently form lakes. *Moorland waters* come from surfaces which may be covered with grass, heather, or bracken, may be of a peaty nature, or may be under cultivation or used for pasturage.

A water supply may be taken direct from the river at some point in its course. If the water is obtained from the river near its source or from the gathering grounds it must be collected and stored in an *impounding reservoir* made by constructing a dam across the foot of the head valley through which the river runs. A supply taken from the upper reaches of the river will tend to be much purer than one taken direct from the lower reaches. In addition to drainage from agricultural land the latter may receive the effluent from a sewage works, which in turn may treat, in addition to sewage, a variety of trade wastes.

Protection of gathering grounds. It is important, especially in the case of water undertakings drawing their supplies from relatively pure upland waters, that gathering grounds should be protected so far as possible from sources of pollution, particularly human sources. In the past the conditions imposed on gathering grounds have varied widely among the different undertakings. Some have bought the greater part, or even the whole of the land draining into their reservoir. Restrictions range from those who endeavour to prevent all human access except their own staff to those who exercise no control at all. A few undertakings try to exclude all animals, including sheep; most allow or encourage sheep, but many prohibit cattle or cultivation, either entirely or within varying distances of the reservoir. These issues are considered at length in the Report of the Gathering Grounds Sub-Committee of the Central Advisory Water Committee,[1] who had to decide whether any kinds of restriction at present in force could be so modified as to provide increased scope for food production and open air recreation without endangering the purity of water supplies. The Report emphasises the vital distinction between human and animal pollution and quotes Sir William Savage, who said " Farming activities involve animals grazing and dropping their dejecta, and the manuring of fields. In other words, animal excreta will get on the land. The pathogenic organisms which are water-borne do not affect animals, so such animal excreta are not a means of spreading them. The comparative unimportance of animal manurial contamination has been discussed. These animal pollutions are, however, a serious nuisance in connection with laboratory control".

The Report suggests that the principle to be followed in the control of gathering grounds is that the water entering the reservoir should be kept free from gross pollution, that the reservoir itself, and in some cases feeder streams, should be so protected as to prevent any fresh sources of pollution entering it directly, and thus short-circuiting the purifying effect of storage, and that between the reservoir and the consumer there should be efficient filtration and sterilisation.

The Committee's recommendations for the conduct of the gathering grounds of upland reservoirs where adequate purification processes exist are summarised as follows:

(i) Arrangements should be made to dispose of the sewage from human habitations, whether permanent or temporary, in a manner which will entirely preclude the possibility of its getting into the reservoir.

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[1] Min. Hlth. (1948), *Gathering Grounds. Public Access to Gathering Grounds. Afforestation and Agriculture on Gathering Grounds*, H.M.S.O.

(ii) Farmyard manure should be prevented from draining directly into feeder streams or reaching the reservoir.

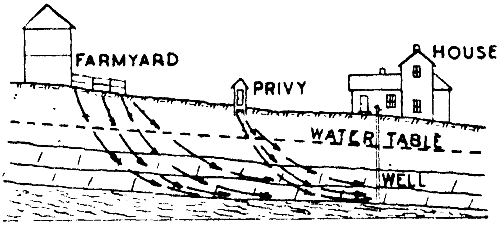
(iii) The public should be generally excluded from the banks of reservoirs, and no bathing should be allowed. Fishing and boating may, in some cases, be allowed at the Undertaker's discretion, but only under rigorous control; restrictions applicable to reservoirs will, in some circumstances, apply equally to feeder streams.

(iv) Subject to the above safeguards, the land should be put to the utmost agricultural use (we are satisfied that many gathering grounds could be put to greater agricultural production than at present).

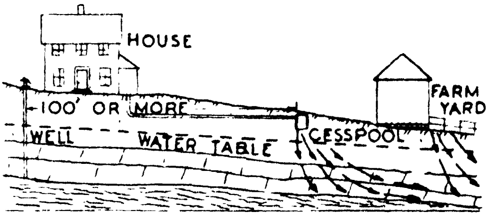
(v) Land which is incapable of agricultural use should, if possible, be afforested, but with due regard to amenity and the requirements of adjacent agriculture.

(vi) Subject to the foregoing recommendations, there is no reason to exclude the public from gathering grounds as such.

Wells and bore holes. A shallow well should be carefully sited so as to avoid pollution from cesspools, or drainage from manure heaps or any other source. The flow of sub-soil water tends to follow the slope of the land and a well should be so placed that this flow tends to carry polluting matter away from it. This principle is illustrated in Fig. W 2.



UNSATISFACTORY LOCATION



SATISFACTORY LOCATION

FIG. W 2.—*Pollution of wells by domestic sewage. Location of well in relation to cesspool and farmyard.* (*After Wright* (*loc. cit.*)).

Methods of sinking wells and the main principles to be observed are described by Adams *loc. cit.* and Wright.[1] A shallow well should be provided with a solid foundation of cement and brick to take the weight of the lining or steining. A 9 in. brick lining is best laid in two rings of 4½ in. and, by laying the bottom two courses in cement, a sump is provided in which any sediment will collect and will not be stirred up by fresh water entering the well. Open-jointed bricks are laid up to a point about a foot below the lowest level of sub-soil water, above which the lining should be solid 9 in. brickwork, set in cement and backed with 6 in. of puddle. This prevents percolation into the well of polluted water from the surface layers of soil. Instead of bricks large stoneware pipes, perforated in the lower sections and cement-jointed in the upper sections may be used. The top of the well should be finished with every precaution against pollution. For this reason the cement rendering should extend several inches above the surface of the ground, which should slope away from the well, and a watertight cover should be fitted. In Fig. W 3 the construction of such a well is illustrated diagrammatically.

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[1] Wright (1939), *Rural Water Supply and Sanitation*, London, Chapman and Hall.

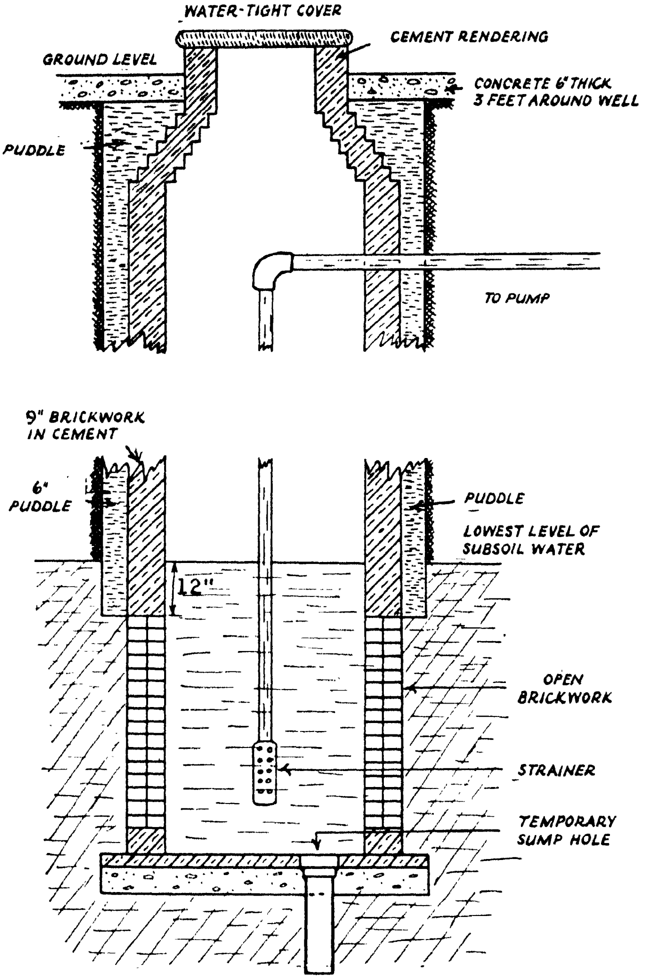

FIG. W 3.—*Construction of Well.*
(*Adapted from drawings by Adams* (*loc. cit.*)).

In this case the water is taken off by a power pump located at a distance. This can, of course, be replaced by a hand pump located at the surface.

A *driven well*, which may be either shallow or deep, consists of a steel tube driven into the earth. At the bottom is a cast steel point surmounted by a short length of perforated tubing through which water can enter. At the top the tube is fitted with a suction pump. Driven wells can only be located in districts where there are comparatively soft strata between the surface and the water which is available.

A *bore hole* is a well drilled into the ground to tap water at a considerable depth, usually beneath an impervious stratum of rock. In one method of boring, the initial hole is made by a chisel attached to iron rods which are held and rotated by means of a trestle and winch, and the process is completed by means of a circular tube with a cutting edge on the bottom. The upper part of the hole is then lined with a steel casing. With a suitable pump, water is withdrawn through a pipe inside this casing, the lower end being fitted with a strainer which allows ingress of water.

If the rate at which water is pumped from a well exceeds the rate at which the subsoil water can travel towards the well intake a "cone of depression" (illustrated in Fig. W 4) will be produced, the level of the water in the immediate neighbourhood of the well tending to be drawn downwards. It is important to remember that the greater the cone of depression the larger is the area over which drainage, conveying possible pollution, may reach the well. Suckling[1] states that when searching for possible sources of pollution this area should be regarded as not less than the area of a circle the radius of which is twenty times the depression of the water level produced by pumping. In porous subsoils the cone of depression may, in fact, be considerably larger than this.

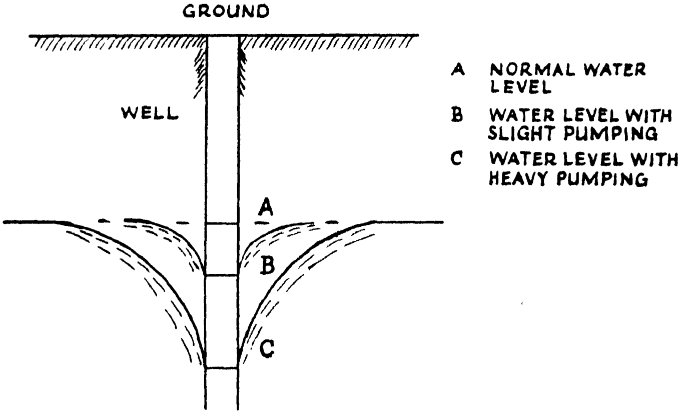
GROUND
WELL
A
B
C
A NORMAL WATER LEVEL
B WATER LEVEL WITH SLIGHT PUMPING
C WATER LEVEL WITH HEAVY PUMPING

FIG. W 4.—*Cone o Depression* (*after Adams* (*loc cit.*)).

Sources of pollution of a shallow well must be in the near neighbourhood, but reference to Fig. W 1 will show that a deep well may be polluted by a source at a considerable distance.

THE CHEMICAL CHARACTERISTICS OF WATER SUPPLIES. Pure rain-water contains comparatively small quantities of dissolved and suspended matter and a very small number of bacteria. When it falls on to the earth and flows over its surfaces or percolates through its upper strata it dissolves some of the chemical substances with which it comes into contact and may retain some of them in suspension. It also acquires a bacterial flora. Both the chemical and the microbial content of a water supply vary very widely according to the source. For a detailed treatment of the subject the reader is referred to the well-known work by Suckling (*loc. cit.*).

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[1] Thresh, Beale and Suckling (1949), *The Examination of Water and Water Supplies*, 6th edition, ed. Taylor, London.

The chemical characteristics of a water supply depend primarily on the geological formation from which it is derived. They are considerably modified, particularly in surface waters, by the nature of polluting material which drains or flows into the water. Nearly all waters contain sodium, calcium, magnesium, chloride, carbonate, sulphate, small amounts of silicate, and small traces of organic matter. There may also be present nitrate, iron, manganese, and lead. Dissolved gases include oxygen and nitrogen, taken up from the air, and carbon dioxide derived from the soil or from decomposing organic matter. The quantity of organic matter may be considerable and is often present in the colloidal condition in the less pure waters.

Suckling divides natural waters into three groups: (i) Acidic waters with a *p*H value of 4·5 or less, which contain free acid other than carbonic and which are usually moorland waters. (ii) Alkaline waters with a *p*H value of 8·5 or more, which contain sodium carbonate and little or no free carbonic acid. (iii) Neutral waters with a *p*H value between 6 and 8. Most potable waters are included in this category and they may be further classified into sub-groups according to their content of dissolved salts.

The composition of the water in a river varies very considerably along its course and is greatly affected by rainfall, which, in addition to diluting the dissolved and suspended material already present, also washes a further quantity in. Discharge to the river of sewage effluent or other source of pollution greatly increases the content of organic matter, ammonia, and bacteria in the near neighbourhood. Biological activity, however, changes the picture rapidly and in the course of a comparatively short period of flow the process of *self-purification* results in considerable removal of organic matter, partly by sedimentation and partly by bacterial oxidation, and in conversion of the ammonia to nitrate.

Although in this country a long tradition has set a high standard for the chemical quality of drinking water, the standard is not closely defined. In the United States, on the other hand, more precise definitions obtain. The upper limits (shown in brackets, as parts per million) for various constituents are as follows and give a useful idea of the order of purity required in a drinking water: lead (0·1), copper (0·2), zinc (5·0), iron (0·3), sulphate (250), magnesium (100), total solids (1000), chloride (250). Manganese, although not included in the American standards, is of the same order of importance as iron.

It is impossible in a short article to give useful information on the methods of chemical analysis of water, but the reader who requires it will find full and precise information given by Suckling (*loc. cit.*) and by the American Public Health Association.[1]

The presence of *organic matter* may not be deleterious to health but it is an indication of lack of purity and represents potential faecal pollution. Accepted indices of organic matter are the values for *biochemical oxygen demand* (B.O.D.), *amount of oxygen absorbed from acid permanganate* (O.A.) and *albuminoid ammonia*. For definitions of the first two values the reader is referred to the section on " Effluent ". Albuminoid ammonia is the ammonia released on boiling the water with an alkaline solution of potassium permanganate, the free ammonia having been previously removed by simple distillation from an alkaline solution. Very clean river waters should have a B.O.D. of less than 0·1 part per 100,000. The order of purity represented by values for O.A. and albuminoid ammonia may be seen from the following average figures (parts per 100,000) given by Suckling:

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[1] American Public Health Association (1946), *Standard Methods for the Examination of Water and Sewage*, 9th edition, New York.

	O.A.[1]	*Albuminoid ammonia*
Potable waters	0·119	0·011
River waters	0·31	0·026
Sewage effluents	1·20	0·114

Hardness is an important property of water, both for domestic and for certain industrial purposes. It is due mainly to the bicarbonates and sulphates of calcium and magnesium and can be measured by standardising a soap solution against a solution of calcium chloride and then measuring the quantity of soap solution which must be added to 50 ml. of the water in order that a " permanent " lather (*i.e.* one which persists for 5 min.) may be formed. The hardness is expressed in terms of calcium carbonate, as parts per 100,000. Carbonates in water are held in solution as bicarbonates by the dissolved carbon dioxide, and when the water is boiled the latter is driven off and the calcium and magnesium carbonates are precipitated. For this reason hardness due to carbonates is known as *temporary* and that due to sulphates, which persists on boiling, is called *permanent hardness*. It is now more usual to determine temporary hardness as the total alkalinity to methyl orange. The neutral solution resulting from this determination (in which the hardness is now all in the permanent form) is then acidified slightly and boiled to expel carbon dioxide. After neutralising to phenolphthalein the total hardness is then determined by titration with a solution of potassium palmitate (previously standardised against barium chloride) until a pink colour develops. Recently a method of determining total hardness has been described by Diehl, Goetz and Hach,[2] and Betz and Noll,[3] and is finding favour in water works practice. The water is titrated with sodium versenate (the disodium salt of ethylenediaminetetracetic acid) at *p*H 10 in presence of Eriochrome black T as indicator. During the titration the versenate first combines with the free calcium ions, next with the free magnesium ions, and finally, at the end point, extracts magnesium from the magnesium-dye compound, changing the colour from wine-red to blue. The versenate is standardised against a solution of calcium chloride of known strength. Calcium and magnesium in the water may be determined separately by precipitating the calcium with ammonium oxalate.

MICROBIOLOGY OF WATER SUPPLIES. That lakes and streams provide a natural habitat for a wide variety of the easily visible forms of life, both animal and vegetable, is common knowledge. The microscopic and the barely visible forms, though unrevealed to the ordinary observer, play an essential part in the cycle of changes which occur in the chemical constituents of water, and in turn they provide food for the larger animals and plants. They include fungi, algae, protozoa, rotifera, and certain small groups of worm-like animals.

The bacterial flora of pure lakes and streams consists largely of Gram-negative, rod-shaped bacteria with poorly marked biochemical characters which are therefore difficult to classify. Pollution by sewage or sewage effluent carries with it a characteristic intestinal flora, among which the coliform bacteria and the faecal streptococci are prominent. The counts of these organisms are for this reason largely used as indices of faecal pollution and therefore of a potential source of pathogenic bacteria.

Routine bacteriological examination. The technique most commonly used in this country for the routine bacteriological examination of water supplies is that outlined by the Ministry of Health.[4] After a standard procedure has been followed for taking the sample, transporting it and preparing it for examination, serial dilutions are prepared in the usual way in one-quarter strength Ringer solution. In the *full bacteriological examination* determinations are made of the *plate counts on nutrient agar at* 22° *C. and at* 37° *C.* and of the *presumptive count of coliform bacteria* at 37° C. and tests are made for *faecal streptococci* and for *Clostridium welchii.* The *partial examination* yields results for plate counts and for coliform bacteria, and in the *simple examination* only the coliform bacteria are counted. In each case the coliform count may or may not be accompanied by differentiation of the organisms into faecal and non-faecal types.

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[1] Values obtained in 3 hr. at 37° C., which are practically the same as 4 hr. at 27° C.

[2] *J. Amer. Water Wks. Ass.* (1950), **42**, 40.

[3] *Ibid.* (1950), **42**, 49.

[4] Reports on Public Health and Medical Subjects. No. 71, "The Bacteriological Examination of Water Supplies" (1946), Ministry of Health, London, H.M.S.O.

Plate counts are determined in the usual way, using a medium containing 0·3 per cent. yeastrel, 0·5 per cent. peptone, and 1·5 per cent. agar. Plates are incubated at 22° C. for 66 to 72 hr. and at 37° C. for 42 to 48 hr. When the sample of water is known to be comparatively pure, inocula of 1 ml. and $\frac{1}{10}$ ml. only are used.

For the presumptive coliform count bottles containing 50 ml. and 6 in. × $\frac{3}{4}$ in. test-tubes containing 10 ml. of double-strength MacConkey broth, and 6 in. × $\frac{5}{8}$ in. test-tubes containing 5 ml. of the single-strength broth, are used. If the sample of water is known to be fairly pure it is sufficient to inoculate one 50 ml. quantity and five 10 ml. quantities into double strength MacConkey broth. For less pure samples it is necessary to inoculate also five 1 ml. quantities into single strength broth. For polluted samples the larger inocula may be omitted and five 1 ml. quantities of suitable serial dilutions inoculated into further tubes of broth. Bottles and tubes are incubated at 37° C. and the count of gas-forming organisms is noted after 18 to 24 hr. and again after 48 hr. Counts are expressed as the most probable number (M.P.N.) of coliform organisms present in 100 ml. of water, this figure being obtained from statistical tables compiled by McGrady. The following examples will make the method clear :

Sample	*No. of tubes giving positive reaction with inocula of*				*M.P.N. per 100 ml. of water*
	50 *ml.* (1)[1]	10 *ml.* (5)[1]	1 *ml.* (5)[1]	$\frac{1}{10}$ *ml.* (5)[1]	
1	0	1	—	—	1
2	1	0	—	—	2
3	1	3	0	—	8
4	—	3	1	1	14

[1] Figures in brackets indicate the number of tubes inoculated.

The coliform bacteria may be broadly divided, for purposes of assessing degree of contamination of water, into two main groups : (i) faecal organisms, typified by *Bact. coli*, whose natural habitat is the human or animal intestine, and (ii) the intermediate-*aerogenes-cloacae* (I.A.C.) group, frequently found on certain types of vegetables and in the soil. The classification of these organisms and the tests used foı the purpose are discussed elsewhere (p. 262). Table W I shows the reactions of the coliform bacteria to the tests recommended by the Ministry of Health (*loc. cit.*) with an indication of their probable habitat.

Alternative techniques may be adopted in differentiating the coliform bacteria. In one method inocula from positive tubes in the presumptive test are streaked on plates of MacConkey's neutral-red bile-salt lactose agar which are then incubated at 37° C. Pure cultures, obtained by inoculating single colonies into tubes of peptone water are then subjected to the differential tests listed in Table W I. As it has been shown that ability to grow in MacConkey broth at 44° C. is largely specific for faecal coliform bacteria, the presumptive count of these organisms may be obtained by sub-culturing positive tubes in the 37° C. test to fresh tubes of media, which are then incubated in an accurate, thermostatically-controlled water bath at 44° C. and examined after 24 to 48 hr.

Examination for faecal streptococci is not recommended as a routine procedure but only as an aid in interpreting doubtful results in tests for coliform bacteria. For research purposes, however, enumeration of faecal streptococci, using a broth containing sodium azide,[1, 2, 3] may yield results of considerable interest. The *Clostridium welchii* test, on the other hand, is recommended for detection of remote or intermittent pollution, especially in shallow well waters, its value depending on the fact that the organism is a natural inhabitant of the intestine and that its spores may be expected to survive under conditions when the less resistant coliform bacteria and streptococci have died out.

TABLE W I

DIFFERENTIATION OF THE COLIFORM GROUP

	M.R.	*V.P.*	*Growth in citrate*	*Indole*	*Gas in MacConkey broth at 44° C.*	*Gelatin liquefaction 7 days*	*Probable habitat*
Bact. coli Type I, faecal .	+	−	−	+	+	−	Human and animal intestine
Bact. coli Type II . .	+	−	−	−	−	−	Doubtful; probably not primarily intestinal
Intermediate Type I	+	−	+	−	−	−	Mainly soil
Intermediate Type II . .	+	−	+	+	−	−	Mainly soil
Bact. aerogenes Type I . .	−	+	+	−	−	−	Mainly vegetation
Bact. aerogenes Type II . .	−	+	+	+	−	−	Mainly vegetation
Bact. cloacae	−	+	+	−	−	+	Mainly vegetation
Irregular Type I . .	+	−	−	+	−	−	Human and animal intestine
Irregular Type II . .	+	−	−	−	+	−	Doubtful
Irregular Other types .			Reactions variable				Doubtful

It is important to remember that unless pollution is obvious, the purity of a water supply should not be judged as the result of a single examination but, preferably, as the result of several examinations over an extended period. For

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[1] Hannay and Norton (1947), *Proc. Soc. Appl. Bact.*, p. 39.

[2] Allen, Pierce and Smith (1953), *JH*, **51**, 458.

[3] Childs and Allen (1953), *JH*, **51**, 468.

non-chlorinated piped supplies the Ministry of Health (*loc. cit.*) recommends the following classification:

		Presumptive coliform count per 100 *ml.*
Class 1.	Highly satisfactory . .	less than 1
Class 2.	Satisfactory . . .	1 to 2
Class 3.	Suspicious	3 to 10
Class 4.	Unsatisfactory . . .	greater than 10

Throughout the year 50 per cent. of samples should fall into Class I, 80 per cent. should not fall below Class 2, and the remainder should not fall below Class 3. Chlorinated piped supplies should be of the quality of Class 1. If, in a non-chlorinated piped water supply, a fall occurs to Class 3, an immediate examination should be made to find out whether the coliform organisms are mainly of the faecal or non-faecal (I.A.C. and irregular) types. If they are found to be of the faecal *coli* type, then steps should be taken to insist on greater purity of supply. If they are of the non-faecal type, further steps towards greater purity of supply need not be taken at once, but analyses of the water should be made more frequently in case the appearance of non-faecal types heralds the advent of more serious pollution. With deep well, or other very pure waters, which normally fall into Class 1, a drop even to Class 2 should not be neglected, and an attempt should be made to detect any possible source of pollution.

Algae. Of the large number of microscopic plants and animals, other than bacteria, which may be found in natural waters, all taking part in a cycle of biological and chemical changes, the algae, which are plants, are of particular importance. Their growth is encouraged by the presence of dissolved carbonates, nitrates, phosphates, and silica. Under the action of light they assimilate carbon dioxide, use the carbon to build further cellular material and liberate oxygen. In this way they perform the double function of manufacturing organic matter and aerating the water. Excessive algal growth, followed by death and decay of the organisms, may give rise to unsightly appearances and foul odours. As an example of what abundance of algae may mean in waterworks practice, Pearsall and co-workers[1] mention that a reservoir supplied by Thames water might contain at times 110 tons (dry weight) of the diatom *Fragilarea crotonensis* which would involve daily removal of one ton of the alga from the water being filtered.

Iron and sulphur bacteria. Growth of these organisms depends on the presence in the water of organic matter—an apparent anomaly as species of both groups are autotrophic. In well-aerated water any iron present is in the form of ferric compounds most of which are almost insoluble in neutral or alkaline conditions. Presence of organic matter, however, encourages the growth of a heterogeneous bacterial flora which depletes the oxygen supply. Under anaerobic conditions the ferric iron tends to be reduced to the ferrous condition and to go into solution, and the growth of iron or sulphur bacteria may be encouraged. These conditions are sometimes found in open reservoirs and are particularly met with below slow sand filters with a heavy algal or bacterial film.

Iron bacteria may use the dissolved carbon dioxide as a source of carbon for growth and the ferrous iron, which they oxidise to insoluble ferric compounds and deposit in their slimes or sheaths, as a source of energy. Their development may give rise to hard deposits in pipes, which seriously reduce their carrying capacity, to accumulation of slime and " streamers " on the sides of pipes and tanks, and to discoloration, turbidity, unpleasant taste and odour, and formation of scum. Sudden and profuse development of iron bacteria, such as may give rise to " red water ", are sometimes referred to by engineers as " water calamities ". The genera most commonly encountered in water supplies are:

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[1] For fuller information the reader is referred to *Freshwater Biology and Water Supply in Britain* by Pearsall, Gardener and Greenshields (1946), Scientific Publications No. 11, Freshwater Biological Association.

Clonothrix,[1] consisting of cylindrical cells enclosed in a sheath to form filaments, which are attached at the base, taper towards the top and show false branching. Reproduction takes place by means of spherical conidia. A well-known species is *Clonothrix fusca.*

Leptothrix [1] is found characteristically as straight threads, about 2 μ. thick and 200 μ. or more long, with a delicate mucillaginous sheath. Young threads show no transverse divisions or branches and are non-motile. Fragmentation occurs later and removal of the sheath with acid reveals the presence of cylindrical cells. Reproduction also occurs by means of motile cylindrical swarmer cells or conidia. *Leptothrix ochracea* is perhaps the most widely distributed of the iron bacteria and may predominate in exposed waters.

Crenothrix,[1] of which *Crenothrix polyspora* is the best known species, consists of unbranched filaments attached at one end, a cluster of such threads sometimes arising from the same particle of foreign matter. Cells are cylindrical to spherical in shape and are visible through the sheath in the unstained condition, giving rise to an appearance likened by Ellis [2] to a long test tube filled with marbles. Though the organism is frequently present in water, conditions necessary for abundant multiplication rarely occur. When they do arise, for reasons which are at present obscure, growth may be sudden and extensive.

Gallionella has a characteristic appearance which enables it to be recognised in microscopic preparations. Individual cells are small curved rods about 0·5 μ. by rather more than 1·0 μ. They secrete on one side of the cell a ferric deposit which takes the form of a twisted ribbon supporting the cell at one end, though the cell is often not visible at all. Depending on the maturity of the specimen and extent of incrustation with iron, it may have the appearance of a twisted hairpin, a stick of barley sugar, or a string of beads. Though widely distributed and often occurring in association with *Leptothrix*, *Gallionella* is found particularly in places where light is excluded and for this reason is most often the cause of deposits in tunnels, mains and pipes.

Sphaerotilus is a genus of thread-forming organisms sometimes associated with iron bacteria, though the organisms do not themselves secrete iron. Rod-shaped or oval cells, surrounded by a soft and slimy sheath, form long filaments attached at the base and showing false branching. *Sphaerotilus natans* is the main constitutent of " sewage fungus " and is found in water containing organic matter, particularly sewage.

With the exception of *Gallionella* identification of the iron bacteria is difficult because of their pleomorphism and the confusing effect of incrustration with iron, which occurs in the older deposits. Typical appearances are, however, indicated in Fig. W 5. Microscopic examination may be made in the untreated and unstained condition, after treatment with dilute hydrochloric acid to remove excess deposit of iron, or after staining with methylene blue or iodine.

Sulphur bacteria are so called because sulphur is necessary for their metabolism. Thus *Beggiatoa alba* is usually found as a white or greyish coating at the bottom of stagnant or slowly moving water which contains hydrogen sulphide. The latter is decomposed by the organism to elementary sulphur which it oxidises to sulphate, storing the excess sulphur in its cells, often as visible globules. *Beggiatoa* and *Thiothrix* are both thread-like fungi but the group of sulphur bacteria includes rod-shaped organisms, cocci and spirilla. The conditions under which they grow, in presence of organic matter which is decomposing to form hydrogen sulphide, are not usually suitable for multiplication of iron bacteria, so that the two groups of organisms are not found together.

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[1] Following the work of Pringsheim (1949, *Phil. Trans. B.*, 233, 453), there is an increasing tendency to simplify the classification of the iron bacteria by regarding many of the genera as environmental varieties of *Sphaerotilus* (*see* Bissett and Grace in *Autrophic Micro-organisms* (1954, p. 44, C.U.P.).

[2] Ellis (1919), *The Iron Bacteria*, London.

Sulphate-reducing bacteria are important as agents of corrosion and are the cause in water distribution systems of the presence of sulphide, objectionable on the grounds of odour or of causing black particles in suspension. The organisms responsible are obligate anaerobes and facultative autotrophs, requiring iron for their nutrition under autotrophic conditions, when carbon dioxide is used as a source of carbon. At ordinary temperatures they are non-sporing curved rods but at higher temperatures their morphology undergoes peculiar changes and above 50° C. they may form spores. The type species is *Desulphovibrio desulphuricans*.

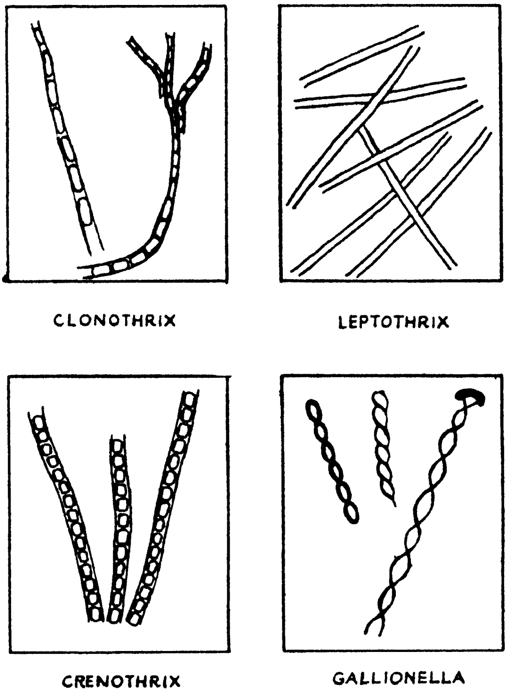

FIG. W 5.—*Diagrams illustrating typical appearances of some Iron Bacteria.*

Different species are morphologically similar and appear to differ only in the type of organic compound which they are able to attack. Sulphate is the specific hydrogen acceptor for these bacteria, the sulphate being reduced to hydrogen sulphide and liberating energy, while an organic compound, serving as source of carbon, is oxidised. A wide variety of compounds, which include organic acids, cellulose and other carbohydrates, alcohols and amino acids, may be so attacked. Thus, lactate is oxidised to acetate according to the following equation :

$$2CH_3.CHOH.COONa + CaSO_4 \rightarrow 2CH_3.COONa + H_2S + CaCO_3 + CO_2 + H_2O.$$

In the presence of sulphate-reducing bacteria corrosion can occur under anaerobic conditions. When corrosion occurs under normal conditions, where there is access to air, ions of the metal pass into solution at anodic points on the surface and hydrogen is discharged at the cathodic points :

$$Fe \rightleftarrows Fe^{++} + 2e \text{ (anodic reaction)}$$

$$2H^{+} + 2e \rightleftarrows 2H \text{ (cathodic reaction)}$$

The system is depolarised by the oxygen of the air, which oxidises the cathodic hydrogen to water. Under anaerobic conditions the cathodic hydrogen is not removed, the system becomes polarised and no corrosion takes place. When sulphate-reducing bacteria are present, however, they activate the cathodic hydrogen, which reduces the sulphate to sulphide. The net result of the reaction may be expressed as follows :

$$4Fe + CaSO_4 + 4H_2O \longrightarrow FeS + 3Fe(OH)_2 + Ca(OH)_2.$$

In certain localities, where the soil contains sulphate and the necessary sulphate-reducing bacteria, external corrosion of water mains constitutes a serious problem. The mains may be protected by thick coatings of bituminous or other suitable material or by embedding them in sand or chalk. Cathodic protection, in which the pipe-line is maintained cathodic with respect to the adjacent earth, is used mainly to supplement the effect of protective coatings, so as to prevent attack at defective points in the line.

TREATMENT OF WATER FOR DOMESTIC AND FOR INDUSTRIAL PURPOSES. A pure and wholesome water supply may be defined as one which contains no organisms capable of causing disease and no chemical substances which are toxic. The water should be clear, colourless, odourless, and free from suspended matter. It should be non-corrosive, reasonably soft, and possess no more than a trace of organic matter. The standard of quality necessary in a particular supply depends on the use to which the water is to be put. Thus in drinking water, or water likely to come into contact with food, provided chemical poisons are absent, freedom from harmful bacteria is more essential than chemical purity. For use in boilers, on the other hand, freedom from chemicals likely to cause scaling is more important than bacterial quality.

Customary water-works practice includes purification by storage, sedimentation, coagulation, and filtration. Most supplies are now also rendered bacteriologically safe by treatment with a disinfectant. In particular cases the water may have to be treated for removal of iron and manganese, for corrosiveness, for hardness, or for prevention of fungal and algal growths.

Storage. Collection of water from a watershed in large impounding reservoirs is commonly practised so that supplies in rainy weather may be stored for use in periods of drought. Such storage may effect an appreciable amount of purification, coarse suspended matter being removed by simple sedimentation and the bacterial count reduced. Prolonged storage is, however, apt to introduce other difficulties. Continual deposition of suspended matter results in time in accumulation of organic matter on the bed of the reservoir and, when conditions become anaerobic, decomposition may lead to formation of materials with unpleasant odours and tastes. Growth of algae on a considerable scale may occur in such reservoirs when exposed to light, more particularly in late spring and early autumn. These not only give rise to objectionable taste and odour but they may introduce serious practical difficulties in the process of filtration.

The advantages of sedimentation, unaccompanied by these difficulties, may be secured to a large extent by the use of smaller reservoirs or of sedimentation tanks, designed for the purpose and commonly made to hold 5 to 7 days' supply.

Coagulation. Material in a finely suspended or colloidal condition, such as may be present in the waters from clay districts or in peaty waters from moorland areas, is not removed by simple sedimentation. It is necessary to use a chemical flocculating agent to form a precipitate which entrains or adsorbs the suspended matter of the water. Aluminium sulphate, alone or in conjunction with lime, and sodium aluminate, alumino ferric, and iron salts are the coagulants most commonly used.

Aluminium sulphate reacts with the calcium bicarbonate in water as follows:

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 \longrightarrow 2Al(OH)_3 + 3CaSO_4 + 6CO_2$$

When used in conjunction with lime or with soda ash the reactions are:

$$Al_2(SO_4)_3 + 3Ca(OH)_2 \longrightarrow 2Al(OH)_3 + 3CaSO_4$$

$$Al_2(SO_4)_3 + 3Na_2CO_3 + 3H_2O \longrightarrow 2Al(OH)_3 + 3Na_2SO_4 + 3CO_2$$

Sodium aluminate reacts with the bicarbonate in water to form flocculent precipitates of calcium and magnesium aluminates:

$$Ca(HCO_3)_2 + Na_2Al_2O_4 \longrightarrow CaAl_2O_4 + 2NaHCO_3$$

$$Mg(HCO_3)_2 + Na_2Al_2O_4 \longrightarrow MgAl_2O_4 + 2NaHCO_3$$

At the same time silica is said to be removed as an insoluble alumino-silicate of calcium or magnesium.

Recently the use of silica sols or " activated silica " as an aid to coagulation has been advocated,[1] and has already become well established in America. The silica is used in conjunction with the usual coagulants, and is claimed to increase the rate of coagulation, of settling and of filtering.

Success in chemical treatment depends on immediate and thorough mixing of the coagulant with the water being treated. Removal of impurities by the chemical flocs is facilitated by continual, gentle circulation of the water after coagulation. For these reasons the process of coagulation is usually conducted in stages. The dose of coagulant may be controlled by a float-operated device so that the quantity of chemical solution added is proportional to the flow of water over a weir. Mixing of the reagent with the water is facilitated if the two flow together, through a channel provided with baffles, into a reaction tank in which rotating paddles, operating at carefully controlled speeds, keep the water in motion for 30 to 60 min. The coagulated water then flows to a settling tank, where a large proportion of the sludge is removed.

TABLE W II

IMPROVEMENT IN QUALITY OF WATER BROUGHT ABOUT BY DOUBLE FILTRATION THROUGH SAND

(after Suckling (*loc. cit.*))

Averages	*Raw water*	*Primary filtered water*	*Secondary filtered water*
Turbidity (silica scale, p.p.m.)	2·7	0·5	0·0
Colour (Hazen scale)	21	16	13
Albuminoid ammonia (parts per 100,000)	0·023	0·016	0·010
Oxygen absorbed in 4 hr. at 26·7° C. (parts per 100,000)	0·206	0·169	0·130
Plate count of bacteria (per ml.) on nutrient agar at 37° C. (1 day)	165	99	32
Percentage of samples containing coliform bacteria in:			
100 ml. or less	100	100	40
50 ml. or less	97	90	10
10 ml. or less	90	40	0
1 ml. or less	33	7	0
0·1 ml. or less	3·3	0	0

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[1] Wheaton and Walker (1950), *Chem. Ind.*, 28 Oct. p. 710 and 16 Dec., p. 802.

Filtration. Water is usually filtered through beds of sand, such beds being classified in two categories according to the rate of filtration.

A *slow sand filter* usually consists of a rectangular basin, built of brick or concrete and suitably underdrained, in which a layer of gravel 1 to 2 ft. deep supports a bed of sand varying in depth in different works from 2 to 5 ft.; this sand must be carefully graded in size. The head of water on the surface is usually 4 to 5 ft. and the rate at which the water passes through the filter is commonly between 1 and 3 million gal. per acre per day.

Slow sand filters are the oldest types of filters and were designed to remove organic matter from water which had not been treated with a coagulant. Their action is partly mechanical and partly biological and, up to a point, becomes more efficient as the layer of impurities and biological film on the surface accumulates. Organic matter and ammonia are removed by the combined processes of sedimentation, mechanical straining, adsorption, and microbial metabolism, which results in part of the organic matter being oxidised to carbon dioxide and part being converted to further microbial cells and in the ammonia being oxidised to nitrate. A large percentage of the micro-organisms in the water is retained by the filter. Results tend to be less good in cold weather, presumably owing to diminution in biological activity.

Rates of filtration may be increased by using two or more filters in series, coarser sand being used in the earlier filter. Results achieved by double filtration of this character may be seen from Table W II. In this case filtration at a rate of 100 million gal. was followed by filtration at a rate of 2 million gal. per acre per day.

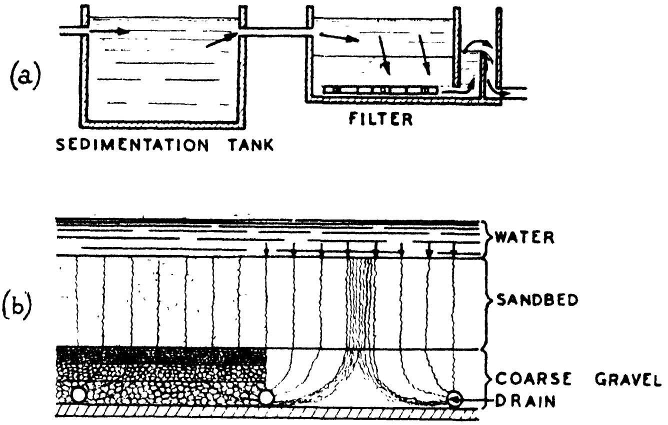

FIG. W 6.—*Diagrams illustrating* (*a*) [1] *passage of water through a slow sand filter, and* (*b*) [2] *section of sand filter.*

Biological growths eventually accumulate to such an extent as to impede filtration. The top layer of sand, which contains most of the clogging material is then scraped off. The intervals at which cleaning must be done vary, according to the character of the water and the time of the year, from a few weeks to several months.

Passage of water through a slow sand filter is illustrated diagrammatically in Fig. W 6.

[1] Adapted from diagram by Babbitt and Doland (1939), *Water Supply Engineering.*

[2] Adapted from diagram by Don and Chisholm (1931), *Modern Methods of Water Purification.*

Rapid sand filters or " *mechanical filters* " are of two types—the open gravity filter, housed in a concrete chamber, in which the water flows through the sand by gravity, and the enclosed pressure filter, in which the filtering medium is contained in a steel case and the water is forced through it under pressure. In both types a system of pipes at the bottom of the bed allows water to be forced upwards through the bed in order to cleanse the surface layers—the so-called " backwashing " process. For both types filtration is usually preceded by coagulation, for the action of the rapid sand filter is one of mechanical straining and is not designed to remove colloidal material. The flow of water through a gravity filter is illustrated in Fig. W 7 and a diagram of a pressure filter is shown in Fig. W 8.

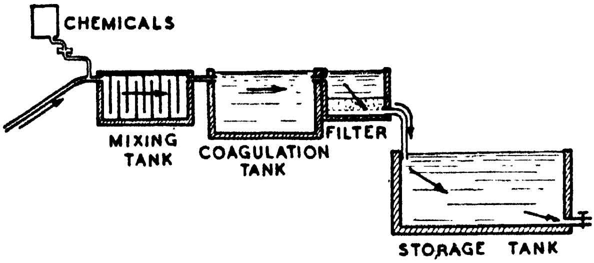

FIG. W 7.—*Diagram illustrating passage of water through rapid sand filter.* (*Adapted from diagram by Babbitt and Doland* (*loc. cit.*)).

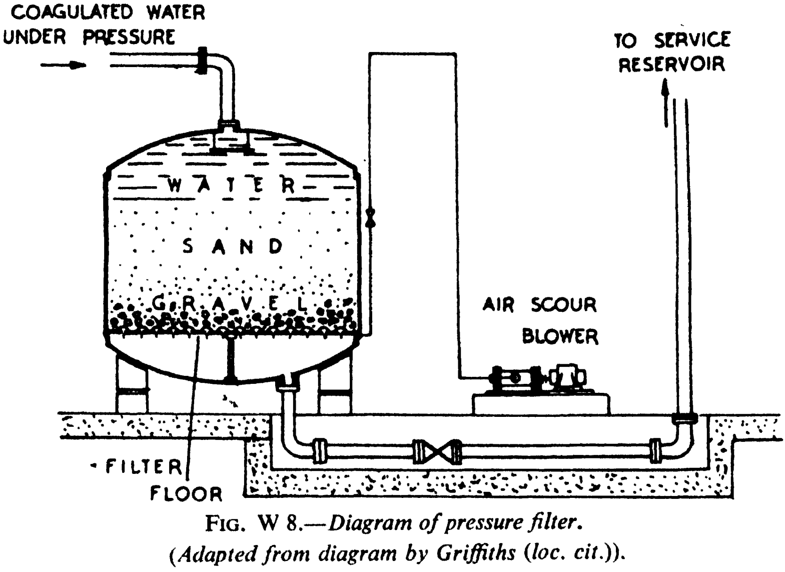

FIG. W 8.—*Diagram of pressure filter.* (*Adapted from diagram by Griffiths* (*loc. cit.*)).

Disinfection. In this country treatment with chlorine is by far the most widely accepted method of sterilising water supplies. There are, however, a number of other agents used to destroy bacteria which may be briefly mentioned.

Ozone is used in many continental plants but less commonly in this country. Ozonised air, produced by a silent electric discharge, must be quickly and intimately mixed with the water either by an injector or by passing the air upwards through a tower in which the water is descending. As the concentration of ozone required to sterilise the water is of the order of 2 parts per million and the ozonised air contains 0·1 to 1·0 per cent. of ozone by weight, the volume of air required is very considerable, amounting on the average to about one third of the volume of water to be treated. An active oxidising agent, ozone has the disadvantage that it reacts very readily with organic matter in the water, which reduces the amount available as a bactericide. On the other hand it removes colour and certain tastes and odours from the water, and as it decomposes into oxygen it leaves behind no substances likely to be irritating to consumers.

The " Katadyn " silver process depends on the use of a sand filter in which the grains of quartz sand have been coated with metallic silver prepared by inflation or blasting. This silver has a micro-crystalline structure which gives it a high ratio of surface to volume and therefore a very powerful oligodynamic action. Suckling (*loc. cit.*) investigated the process and found that minute amounts of silver were taken up by the water during filtration. Provided a period of contact of 2 to 12 hr. was subsequently allowed, adequate sterilisation could be attained with a pure water at average temperatures. Presence of organic matter in the water, however, clogged the surface of the sand and prevented any action of the silver, and low temperatures greatly decreased efficiency of sterilisation.

Treatment of water with chlorine. Chlorine may be used either as liquid chlorine for large-scale practice, or in the form of hypochlorites for small-scale and emergency practice. Drums containing up to 1 ton, or cylinders containing about 70 lb. of liquid chlorine are connected to a dosing apparatus, or chlorinator. which intimately mixes chlorine gas, delivered at a controlled rate, with a stream of water to give a concentrated solution of chlorine, this solution being then mixed with the main bulk of water. Chlorinators should preferably be housed in a brick building insulated from the effects of extreme cold. The precautions to be observed in their use are clearly set out and discussed in an article by Smith.[1]

A variety of hypochlorite preparations, such as bleaching powder, " Chloros " or " Stabochlor ", are available on the market. A solution may be added to the water to be treated either by means of an automatic dosing equipment or by a simpler method, such as allowing the solution to flow slowly from an aspirator into a stream of water being delivered from a pipe into a contact tank. The hypochlorite solution may also be prepared *in situ* by electrolysis of a solution of sodium chloride.

Efficiency of disinfection depends on a number of factors. In addition to being a function of time, of concentration of chlorine and of temperature it is influenced by the amount of organic matter present and by *p*H value ; the proportion of organisms destroyed also depends on the species. When chlorine is added to water a portion of it reacts with any organic matter which is present. If the dose added is less than the amount required to satisfy this *chlorine demand*, the effect on micro-organisms will be comparatively small and uncertain. For efficient disinfection there must therefore be residual chlorine, usually determined by means of the ortho-tolidine reagent, with which both chlorine and chloramine give a yellow colour.

In pure water chlorine is an effective bactericide in very high dilution, a residual value of 0·2 to 0·4 part per million often being considered sufficient in large scale practice. Dosage and time of contact are, however, closely related and as a general rule it may be taken that if the water is clear and bright and there is a residual value of 0·1 part per million after a period of contact of 30 min., the water will be bacteriologically satisfactory. If ammonia is present or if the temperature is low, higher doses or longer periods of contact will be required.

The *p*H value has a profound effect on germicidal efficiency, the time required to kill bacteria being much greater on the alkaline than on the acid side of neutrality. Germicidal action also increases markedly with rise of temperature.

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[1] *J. Inst. Water Eng.* (1950), **4**, 481.

Factors affecting the bactericidal action of chlorine are discussed in a review of the bacteriological aspects of chlorination by Allen.[1] The effect of some of these factors is shown in Table W III.

TABLE W III

Factors Affecting the Germicidal Efficiency of Chlorine

(from figures given by Rudolf and Levine [2])

Results expressed as time required for a given dose of chlorine (as calcium hypochlorite) to destroy 99 per cent. of spores of *B. metiens* in aqueous solution.

Effect of pH value (available chlorine 25 p.p.m., temp. 20° C.)

*p*H value	6·0	7·0	8·0	9·0	9·4	10·0	12·9
Disinfection time (min.)	2·5	3·6	5·0	19·5	35·5	121·0	465·0

Effect of temperature (available chlorine 25 p.p.m., *p*H value 10·0)

Temperature (° C.)	20	30	35	50
Disinfection time (min.)	121	65	38·7	9·3

Effect of concentration of chlorine (initial *p*H value 10·0, temp. 20° C.)

Available chlorine (p.p.m.)	25	100	500
Disinfection time (min.)	121	63·5	31

Prechlorination of water, *i.e.* application of a comparatively large dose of chlorine to the raw water, prior to coagulation and filtration, is sometimes practised where the pollution load is high. In addition to restraining the growth of algae it may effect some economy in the use of coagulants. Since a further but smaller dose is usually added after filtration, a double safeguard against bacterial infection is provided.

Ammonia-chlorine (*Chloramine*) *treatment.* When water containing ammonia is treated with chlorine reaction occurs with the formation of chloramines:

$$NH_3 + Cl_2 \longrightarrow NH_2Cl + HCl$$

$$NH_3 + 2Cl_2 \longrightarrow NHCl_2 + 2HCl$$

Monochloramine is stable at *p*H values above 8·5 ; at *p*H values between 4·4 and 8·5 mixtures of mono- and di-chloramines are formed, the ratio depending on the *p*H value. The figures in Table W IV show that the bactericidal action of the

TABLE W IV

Effect of Ammonia on Germicidal Efficiency of Chlorine

(from figures given by Weber, Bender and Levine[3])

Ammonia content (p.p.m.)	*Time taken for 99% disinfection (min.)*	*Residual chlorine at end of experiment (p.p.m.)*
0·0	3·0	22·0
0·5	3·3	19·0
2·0	6·5	8·7
6·0	89·0	21·1
19·0	84·0	23·8

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[1] *J. Inst. Water Eng.* (1950), **4,** 502.
[2] Iowa Eng. Expt. Sta. (1941), *Bull.* No. 150.
[3] *J. Amer. Wat. Wks. Ass.* (1940), **32,** 1904.

chlorine is considerably reduced by the presence of ammonia. Chloramine is, in fact, not only less powerful as a germicide but is chemically less active than chlorine and therefore more stable. It is for this reason that ammonia-chlorine treatment is applied to water which is subjected to a long period of retention in a reservoir or a main before delivery to the consumer. Absorption of chlorine by organic matter in water is also largely prevented by the presence of ammonia.

Although the above equations show that in theory a ratio of chlorine to ammonia of 4 : 1 for monochloramine and of 8 : 1 for dichloramine is required, the ratio adopted in practice is usually between 3 : 1 and 2 : 1. The quantity of ammonia added must be carefully calculated and depends partly on the natural ammonia content of the water and partly on the dose of chlorine which is to be added. The ammonia is usually added first and sufficiently in advance of the chlorine to allow it to become dispersed throughout the water before meeting the chlorine.

Superchlorination involves the application of excessive doses of chlorine to overcome the objectionable taste which develops by reaction of chlorine with the phenolic compounds which are present in some waters. These chlorophenols are destroyed, probably by oxidation, by sufficient excess of chlorine, doses up to 10 parts per million being used. After a period of contact varying from 1 to 4 hr. the chlorine is discharged by treatment of the water with activated carbon, sulphur dioxide, or sodium sulphite.

Break-point chlorination is a practice which has found an increasing use during the last few years and may really be regarded as controlled superchlorination. When, in certain types of water containing organic matter or ammonia, the value for residual chlorine by the orthotolidine test is determined for increasing doses of chlorine, a curve of the type shown in Fig. W 9(A) is obtained. Thus after a progressive rise at first the quantity of residual chlorine reaches a stage where it falls, sometimes almost to zero, before a second rise occurs. This point is known as the break-point. Its significance lies in the fact that the chloramines and similar chlorine substitution products, formed by reaction with the smaller doses of chlorine, are oxidised by the higher doses ; at the break-point this oxidation is complete and further addition of chlorine results in a residual of true or free chlorine. This may be distinguished by the use of the *p*-amino-dimethylaniline reagent, which gives a purple colour with free chlorine and no reaction with chloramine. Oxidation of the chloramines probably results in formation of nitrogen :

$$2NH_2Cl + Cl_2 \longrightarrow N_2 + 4HCl$$

Reference to Fig. W 9(A) shows that, in presence of ammonia, a given concentration of residual chlorine by the ortho-tolidine test may be obtained by the application of three different doses of chlorine, as at T_1, T_2, and T_3, two of the doses being below the break-point and one dose above it. Since the bactericidal action of free chlorine is much greater than that of a similar concentration of chlorine as chloramine, the dose above the break-point will be much more effective as a sterilising agent than the other two doses. It is important to remember this when using ortho-tolidine as a test reagent for residual chlorine in such waters.

The chemical reactions following chlorination in presence of ammonia have recently been worked out by Palin.[1] The proportions of monochloramine, dichloramine and nitrogen trichloride which are found, and the extent to which they are developed depend on *p*H value as well as on the ratio of chlorine to ammonia. Under certain circumstances appreciable amounts of these substances, particularly nitrogen trichloride, may persist past the break-point. The relative proportions of these substances found at *p*H 7·3 to 7·5 after two different periods of contact are shown in Fig. W 9 (B and C).

Use of chlorine dioxide.[1] Recently chlorine dioxide, formed by the action of

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[1] For further information and a bibliography, *see* Ingols (1950), *J. Inst. Water Eng.*, **4**, 581.

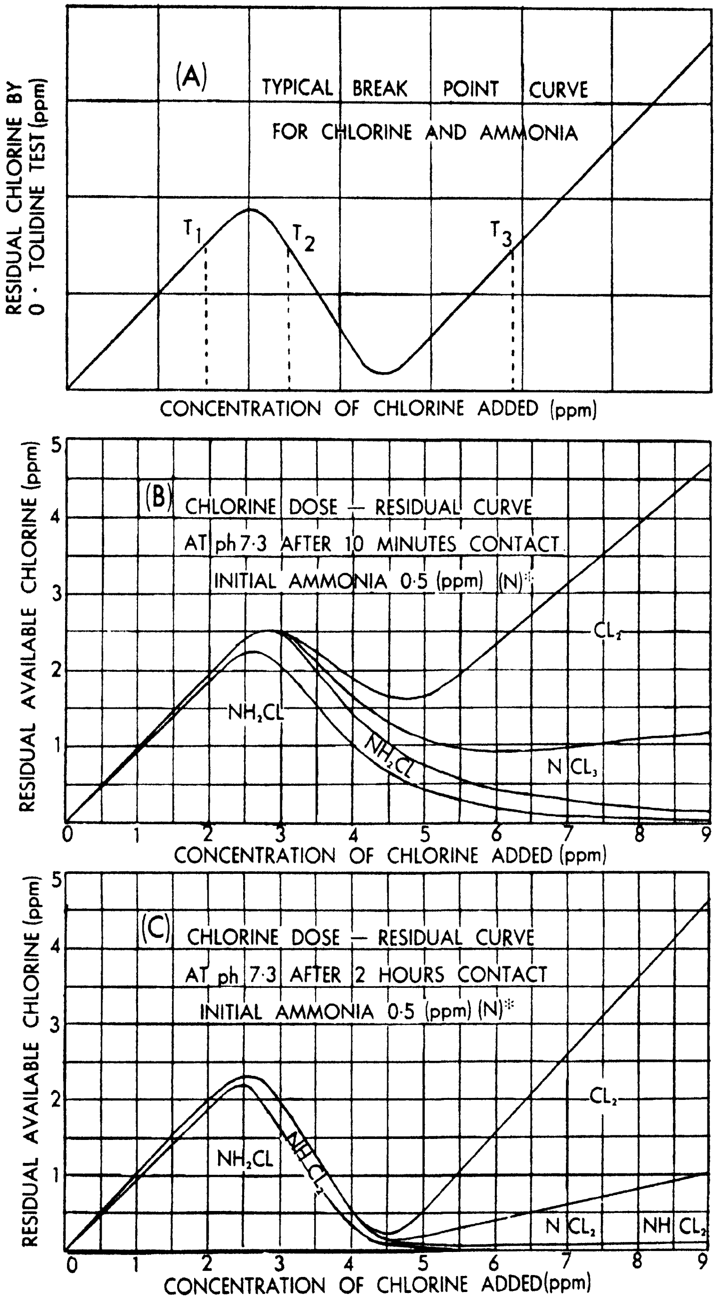


FIG. W 9 (A, B and C).—*Break-point curves for chlorine in presence of ammonia.*

* *After Palin (loc. cit.).*

an acid or of chlorine on sodium chlorite, has been tried with some success for the treatment of water:

$$\mathrm{5NaClO_2 + 4HCl \longrightarrow 4ClO_2 + 4NaCl + 2H_2O}$$

$$\mathrm{2NaClO_2 + Cl_2 \longrightarrow 2NaCl + 2ClO_2}$$

With the production of sodium chlorite on a commercial scale, chlorine dioxide is likely to be more widely used. In America, where a number of plants now use this substance for control of tastes in water, a feasible method of producing chlorine dioxide in solution has been developed by introducing a small volume of a solution of sodium chlorite into the discharge of a vacuum feed chlorinator. After a short period of contact it is then added directly to the water. Chlorine dioxide, which is very unstable or explosive in the gaseous phase, is thus formed in solution, where it is stable and safe to handle. Reports so far suggest that chlorine dioxide is a very effective lethal agent for bacteria, viruses, spores and cysts in water with a low content of organic matter. With polluted waters it tends to be adsorbed on suspended particles and then compares unfavourably with chlorine. In this country the use of chlorine dioxide is still in the experimental stage.

Use of activated carbon in water treatment. " Activated " carbon is carbon manufactured from sources such as wood or peat in such a way as to remove impurities and yield a product with a high porosity. Various grades of activated carbon, which may be either powdered or granular, are manufactured, and are each suited to different purposes. Their main uses in water works practice are for removal of colour, odour, and chlorine and their efficiency depends primarily on adsorption by the relatively enormous surface provided. Thus with chlorine the following reactions appear to occur between constituents highly concentrated by surface adsorption:

$$\mathrm{2Cl_2 + 2H_2O \longrightarrow 4HCl + 2O}$$

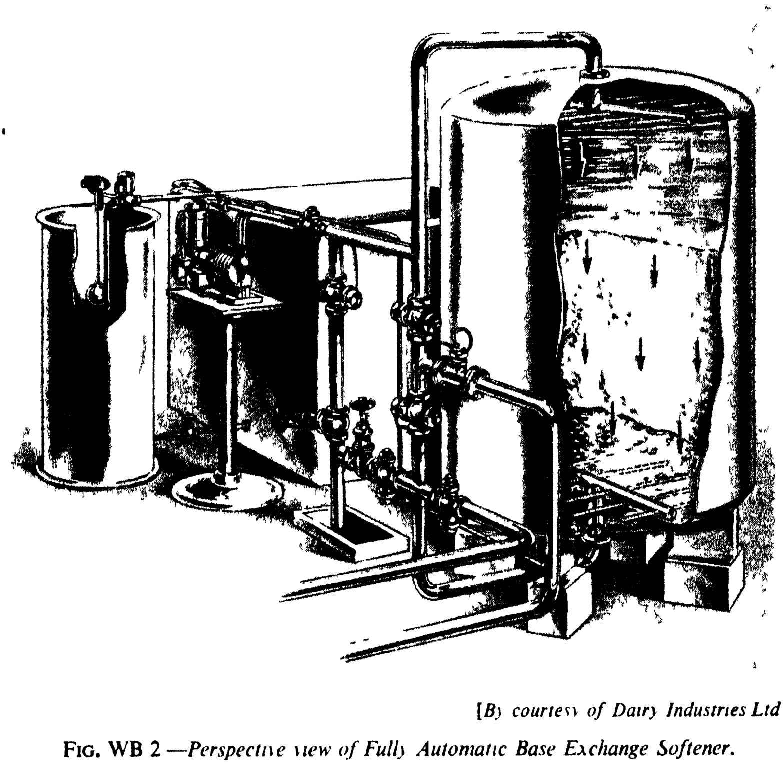
$$\mathrm{C + 2O \longrightarrow CO_2}$$

Powdered carbon may be used, *e.g.* for removal of odour, by preparing a slurry which is added to the water at a constant rate to give a concentration varying from 2 to 20 parts per million. A period of contact of several hours is commonly allowed and the carbon is then removed by passage through a rapid sand filter, which in turn is cleared of carbon by the back-washing process.

For removal of excess chlorine, granular carbon, in the form of a bed similar to a sand filter, is used. The rate of filtration possible will depend on the amount of residual chlorine present but it is usually recommended that the depth of the bed should be not less than 3 ft., when rates of flow up to about 3 gal. per sq. ft. per min. may be obtained. Since the efficiency of the carbon depends on the activity of its surface, any material tending to coat this surface will be detrimental and may be permanently injurious. For this reason water to be so treated should be clear and free from colloidal and suspended matter.

TREATMENT OF WATER FOR SPECIAL PURPOSES. That water may require special treatment for certain purposes has been indicated in the preceding sections. Following is a brief account of the treatments most commonly encountered, together with an indication of the circumstances under which they are used.

Softening of water. As indicated earlier, hard water may result in the formation on dairy equipment and glassware of deposits which are hard to remove, and in boilers of " scale " which lowers efficiency and is costly to remove. When water is heated the bicarbonates of calcium and magnesium decompose and deposit carbonates. This deposit forms when water with temporary hardness is heated to about 70° C. and it therefore occurs in preheaters as well as in boilers. Salts responsible for permanent hardness (mainly sulphates) do not deposit on simple boiling, but in a boiler they become concentrated in the water and eventually crystallise out to form a thick, hard scale; thin hard scales of calcium and magnesium silicates may also be formed. To prevent these troubles the water should



[By courtesy of Dairy Industries Ltd

FIG. WB 2.—*Perspective view of Fully Automatic Base Exchange Softener.*

be subjected to a softening process. Several methods are available and the one chosen should depend on the type of water to be treated and the use to which it is to be put.

Treatment with lime. Temporary hardness may be removed by adding sufficient lime to convert calcium bicarbonate to the carbonate and magnesium bicarbonate to the hydroxide. The process has the disadvantage that it does not remove permanent hardness. Trouble is also sometimes experienced through " after-precipitation " of calcium carbonates, which may not be completely precipitated in the sedimentation tanks. This difficulty is avoided if a small quantity (about 1 part per million) of sodium hexametaphosphate (Calgon) is added to the water.

Lime-soda process. In this process, which removes both temporary and permanent hardness, hydrated lime and sodium carbonate are added in sufficient quantities to precipitate the calcium salts as calcium carbonate and the magnesium salts as magnesium hydroxide. If the treatment is carried out at temperatures of 70° C. or higher the hardness can be reduced to a very low figure, *e.g.* of the order of 1 part per 100,000. In the cold the process is less efficient.

For waters containing appreciable quantities of magnesium, sodium aluminate is used as an additional reagent; it coagulates the finely divided precipitate of magnesium hydroxide into large flocs.

The reagents are suspended in water and added as a " milk ", the quantities being accurately computed for the hardness and volume of the water to be treated, and only a slight excess being allowed. A period of 2 to 3 hr. is allowed for settlement of the precipitate, which is then removed by filtration. As a result of the treatment the calcium and magnesium originally present are replaced by an equivalent quantity of sodium and, if the hardness is high, the resulting water will contain appreciable quantities of sodium salts. Incomplete precipitation, leading to delayed deposition in pipe lines and boilers, may be avoided by " seeding " the mixture of water and reagent with preformed slurry. This principle is incorporated in certain plants in which a proportion of the sludge is re-circulated.

Treatment with zeolites. The base-exchange or zeolite process has long been used for softening water, both for domestic and for industrial purposes. It depends on the property possessed by certain aluminosilicates of exchanging their sodium for the calcium and magnesium in the water. The zeolites in commercial use comprise natural glauconites, treated clays, and synthetic products prepared from sodium aluminate and sodium silicate. In practice the water is passed through a column or bed of the material at a controlled rate. Parker (*loc. cit.*) states that the volume of water which can be treated by 1 cu. ft. of the zeolite to reduce the hardness by 10 parts per 100,000 is approximately 700 gal. with the glauconites, 1100 gal. with the treated clays, and 1800 gal. with the synthetic materials, before regeneration becomes necessary. The material is regenerated for further use by treatment with a solution of common salt, when the calcium and magnesium of the zeolite are again replaced by sodium.

The zeolite process has several advantages. The plant occupies less space than the lime-soda plant, yields a water with a hardness of not more than 1 part per 100,000, and provides no sludge-disposal problem. On the other hand the treated water contains more dissolved solids than the original water, dissolved carbon dioxide is not removed, and corrosive action may be increased. Water should be freed from iron and from suspended and colloidal matter before treatment as these materials are detrimental to the action of the zeolite.

Carbonaceous zeolites are cation-exchange materials prepared by treating carbonaceous substances, such as coal, peat, or lignite, with concentrated sulphuric acid, chloro-sulphonic acid, etc. As the carbonaceous zeolites contain little or no silica and are resistant to acids, they may be regenerated with acid as well as with salt. When regenerated with brine they yield a sodium compound, with properties similar to the base-exchange zeolites; regeneration with acid results in the formation of the corresponding hydrogen compound. Treatment of a water, in which the hardness is mainly temporary, with the hydrogen compound results in replacement of the carbonates and bicarbonates by carbon dioxide, and by removing the latter by aeration a soft water may be produced without introducing fresh substances into solution.

Experiments at the Chemical Research Laboratory made in 1934 as part of the programme of the Water Pollution Research Laboratory resulted in the preparation of *ion-exchange synthetic resins.* Thus cation exchangers were prepared from phenol-formaldehyde resins and anion exchangers from amine-formaldehyde resins.

The properties of softened water in relation to the process for which it is to be used need to be carefully considered. That treatment by the lime-soda or base-exchange process may cause little or no reduction in the content of dissolved salts is shown by the figures in Table W V. In this example the lime-soda treatment has reduced the total solids by about 25 per cent. ; treatment with zeolite has resulted in a slight but definite increase. Chemically treated water may therefore still give rise, when used for boilers, to the undesirable consequences associated with a high concentration of dissolved or suspended matter. These difficulties include foaming and priming, and decomposition of the sodium bicarbonate to carbon dioxide and caustic soda, resulting in corrosion. In low pressure boilers, where water softened by base exchange is often used, trouble may be avoided by frequently blowing down.

TABLE W V

EFFECT OF SOFTENING PROCESSES ON CONTENT OF DISSOLVED SALTS IN WATER

(*Results as parts per* 100,000, *from figures given by Matthews*) [1]

Raw water		*Water after treatment with*			
		Lime-soda		*Sodium zeolite*	
$CaCO_3$	11·4	—		Na_2CO_3	12·1
$CaSO_4$	15·7	Na_2SO_4	16·4	Na_2SO_4	16·4
$MgCO_3$	5·0	—		Na_2CO_3	6·3
$MgSO_4$	11·4	Na_2SO_4	13·6	Na_2SO_4	13·6
NaCl	14·3	NaCl	14·3	NaCl	14·3
Total solids	57·8	Total solids	44·3	Total solids	62·7

Treatment of corrosive and plumbo-solvent waters. Some natural waters have a marked corrosive action on metals and may be responsible for incrustation and pitting of iron water mains and the delivery to the consumers of turbid and discoloured water. Zinc is also attacked and galvanising may not therefore afford much protection. Soft moorland waters of an acidic character, and waters containing appreciable quantities of carbon dioxide, are well known for their corrosive properties but some hard waters may also be corrosive. Waters which will deposit calcium carbonate tend to form a protective coating on metallic surfaces and will not corrode, but waters which will not deposit, or will even dissolve, calcium carbonate tend to be corrosive. Waters in which acidity is due to organic acids are also plumbo-solvent.

Various methods of treatment, designed to increase the alkalinity of the water, are practised. These include controlled addition of lime, chalk, soda, or sodium silicate, passage of the water through beds of limestone chippings or magnesite, and aeration to remove carbon dioxide. In high-pressure boilers oxygen becomes an important factor and the feed water is therefore de-oxygenated.

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[1] Matthews (1939), *Boiler Feed Water Treatment,* 2nd edn., Hutchinson, London.

Removal of algal growth. Growth of algae may occur not only in storage reservoirs but in smaller storage tanks on farms and in factories. Since light is essential for their growth this may be prevented by fitting a cover to exclude the light, a remedy which is obviously impracticable for reservoirs of any size. Algae are inhibited by small concentrations of metals such as copper, silver and zinc, and in practice copper sulphate is most commonly used as an algicide. The same chemical is also effective against growths of protozoa, such as *Euglena*, which may occur at times in such profusion as to cause difficulty in filtration.

TABLE W VI

CONCENTRATIONS OF COPPER SULPHATE REQUIRED FOR ERADICATION OF DIFFERENT MICRO-ORGANISMS

(*from Whipple and Fair, quoted by Suckling* (*loc.cit.*))

Organisms	*Copper sulphate (parts per million)*	*Organisms*	*Copper sulphate (parts per million)*
Cyanophyceae		*Diatomaceae*	
Anabaena	0·12	Asterionella	0·12 to 0·20
Aphanizomenon	0·12 to 0·50	Fragilaria	0·25
Clathrocystis	0·12 to 0·25	Melosira	0·33
Coelosphaerium	0·20 to 0·33	Navicula	0·07
Microcystis	0·20	Synedra	0·50
Oscillatoria	0·20 to 0·50	Stephanodiscus	0·33
		Tabellaria	0·12 to 0·50
Chlorophyceae			
Ankistrodesmus	1·00	*Schizomycetes*	
Chara	0·10 to 0·50	Beggiatoa	5·00
Cladophora	0·50	Crenothrix	0·33
Closterium	0·17	Sphaerotilus dichotomus	0·20
Coelastrum	0·05 to 0·33		
Desmidium	2·00	*Fungi*	
Draparnaldia	0·33	Leptomitus	0·40
Enteromorpha	0·50		
Eudorina	10·00	*Protozoa*	
Hydrodictyon	0·10	Ceratium	0·33
Microspora	0·40	Chlamydomonas	0·50
Palmella	2·00	Cryptomonas	0·50
Pandorina	10·00	Dinobryon	0·25
Scenedesmus	1·00	Euglena	0·50
Spirogyra	0·12	Glenodinium	0·50
Staurastrum	1·50	Mallomonas	0·50
Trobonema	0·25	Peridinium	0·50 to 2·00
Ulothrix	0·20	Synura	0·12 to 0·25
Volvox	0·25	Uroglenopsis	0·05 to 0·20
Zygnema	0·50		

Table W VI shows the concentrations of copper sulphate required to eradicate different organisms ; in general, treatment with 0·5 to 1·0 part per million is effective. The dose may be applied either as a solution, through a pipe-line or spray, or as a solid. For reservoirs of appreciable size a boat may be used to drag sacks of the chemical through the water from end to end of the reservoir until the whole area is covered. It should, perhaps, be added that in large-scale practice elimination of algae sometimes proves very difficult.

Removal of iron and manganese. Objections to the presence in water of appreciable quantities of these metals have been briefly indicated. Amounts less than 0·5 part per million in water to be treated at a works do not normally cause difficulty as the soluble iron compounds are usually oxidised in the course of treatment to insoluble hydroxides, which are removed during filtration. If the water contains larger quantities than this or if it is not subject to treatment at a works these metals may cause turbidity, colour and unpleasant taste, and be responsible for unsightly stains on equipment, floors, and textile materials.

Iron-bearing waters are derived from a number of areas in this country and may have widely different characteristics,[1] varying from little or no hardness and a low mineral content to considerable hardness and a high content of dissolved solids. All these waters contain carbon dioxide, which reacts with the iron ores in the strata from which the water is derived to form soluble ferrous bicarbonate. In waters containing sulphuric acid, such as those from coal-mining areas, the iron may be converted to ferrous sulphate, but the bicarbonate is the usual form in which it occurs. In contact with air this is converted to insoluble ferric hydroxide with resultant turbidity :

$$4Fe(HCO_3)_2 + O_2 + 2H_2O \longrightarrow 4Fe(OH)_3 + 8CO_2.$$

Moderate quantities of iron and manganese may be removed by passage through a specially designed pressure filter containing oxidising catalyst, such as " Polarite ", in addition to ordinary filter sand. Air necessary for the oxidation is provided either by spraying the water into the atmosphere at the top of the filter or by injecting air into the raw water main.

A simple and economical method of treatment consists in open aeration followed by filtration, with or without preliminary sedimentation. Removal of 50 to 60 per cent. of the carbon dioxide, together with incorporation of the necessary oxygen, is secured by spraying the water into the filter tanks through very fine nozzles. Aeration of this kind is less effective when manganese is associated with the iron.

Chemical methods of removing iron and manganese include addition of lime to bring the *p*H value to between 7·5 and 8·5, followed by settlement and filtration, and treatment with a special manganese zeolite, which can be regenerated with a solution of potassium permanganate.

Prevention of fungal growths in cooling water. Large volumes of cooling water may be used at certain factories for circulation through condensers or other heated plant. In order to avoid continual consumption of fresh water it is a common practice to cool the water by passing it over a " tower " (which is usually a large and expensive erection composed of wooden slats) and to recirculate the cooled water by pumping. At some factories the water from the tower flows into a cooling pond before being recirculated to the main water tank. Such water usually has an appreciable content of organic matter. It is evident that water which is recirculated in this way, which is periodically warmed, and which contains organic matter, will encourage the growth of micro-organisms, including " sewage fungus " and slime-forming bacteria. Growths of this character are, in fact, easily visible on the slats of the cooling tower and they frequently choke the orifices which deliver the water at the top of the tower, when no treatment is applied to avoid the trouble. These growths can be prevented by the application of a suitable dose of chlorine at a point in the circuit before the water reaches the cooling tower.

Results of experiments carried out by the Water Pollution Research Laboratory on a cooling water system of this character showed that the chlorine demand of the water ranged from 9 to 13 parts per million. Laboratory tests (Table W VII) with samples of cooling water showed that doses of 2 parts per million or more produced an appreciable reduction in bacterial count after a period of contact of 15 min.

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[1] For further information *see* Griffiths (1945), " The Behaviour and Treatment of Iron-bearing Waters ", *J. Inst. San. Eng.*, **44**, 7.

TABLE W VII

BACTERIAL COUNTS (PER ML.) OF COOLING WATER TREATED WITH DIFFERENT DOSES OF CHLORINE AND AFTER DIFFERENT PERIODS OF CONTACT

(Plate count on nutrient agar)

Period of contact (hr.)	*Dose of chlorine (parts per million)*			
	2	4	6	8
Test I—Chlorine demand of water = 13 p.p.m.				
0	60,000	60,000	60,000	60,000
¼	20,000	5,900	1,800	1,200
2	2,500	1,300	1,000	800
24	1,180,000	550,000	130,000	1,000
Test II—Chlorine demand of water = 8·5 p.p.m.				
0	160,000	160,000	160,000	160,000
¼	44,000	42,000	6,000	9,400
2	7,000	6,000	1,000	500
24	40,000	19,000	11,000	5,000

It seemed likely, therefore, that a dose of the order of 2 parts per million, applied continuously to the cooling water circuit would be effective in preventing micro-biological growth. Average counts of samples of water taken from two points in the circuit during (*a*) two periods without chlorination, and (*b*) one period when a dose of 3 parts per million of chlorine was applied to the pipeline between the condensers and the cooling tower, are shown in Table W VIII.

This effect on the bacterial counts was reflected in the condition of the cooling tower and of the orifices delivering the water to it, which were noticeably free from biological growths. *See* Cleaning and sterilising ; Coliforms ; Detergents ; Effluent ; Management of creameries, of pasteurising depots.

TABLE W VIII

AVERAGE BACTERIAL COUNTS (NUMBERS PER ML.) OF SAMPLES OF COOLING WATER DURING PERIODS OF CHLORINATION AND DURING PERIODS WITHOUT CHLORINATION

	No. of samples tested	*Dose of chlorine (p.p.m.)*	*Average bacterial count of samples from*	
			Pipeline at point between chlorinator and tower	*Top of cooling tower*
Period I . . .	10	nil	495,000	482,000
Period II . . .	12	3	542	388
Period III . . .	4	nil	450,000	355,000

Refs.: " Water in Industry " (1951), *CI*, 1169 to 1234. *See* also Thomas *et al.* (1951), *SAB*, **14,** 121 (farm waters).

WATER, BOILER, CONTROL OF. Effective control of the chemical quality of boiler water is necessary to prevent troubles which may arise due to scale formation, corrosion, foaming, priming and the production of wet steam causing fouling of super-heaters, turbines, etc. The aim of feed and boiler-water treatment (Matthews, 1951, Nordell, 1951) is to prevent these adverse conditions with their attendant failure of boilers and ancillary plant or interruptions in service, and to achieve this aim the feedwater should be as pure as possible.

The treatment and conditioning process may constitute any or all of the following:

(1) Treatment of the make-up water by a softening process, evaporation or deionisation to remove scale-forming and other salts, and auxiliary conditioning, if necessary, to prevent corrosion in feed lines.

(2) Treatment of returned condensate to remove oil and auxiliary conditioning, if necessary, to prevent corrosion in feed lines.

(3) Treatment of the feed water to remove dissolved gases, and auxiliary conditioning to render the water non-corrosive.

(4) Conditioning of the boiler water direct in the boiler drum.

(5) Blowing-down of the boiler, preferably by a continuous system, to control the quantity of dissolved solids in the boiler water.

The extent of the treatment which must be carried out depends largely on the type of boiler and the operating pressure. Thus, for water-tube boilers operating at 1000 lb. per sq. in., feed water of " distilled " quality is essential, while for Lancashire or Economic boilers operating at 100 to 150 lb. per sq. in., water free from hardness salts only is required as feed.

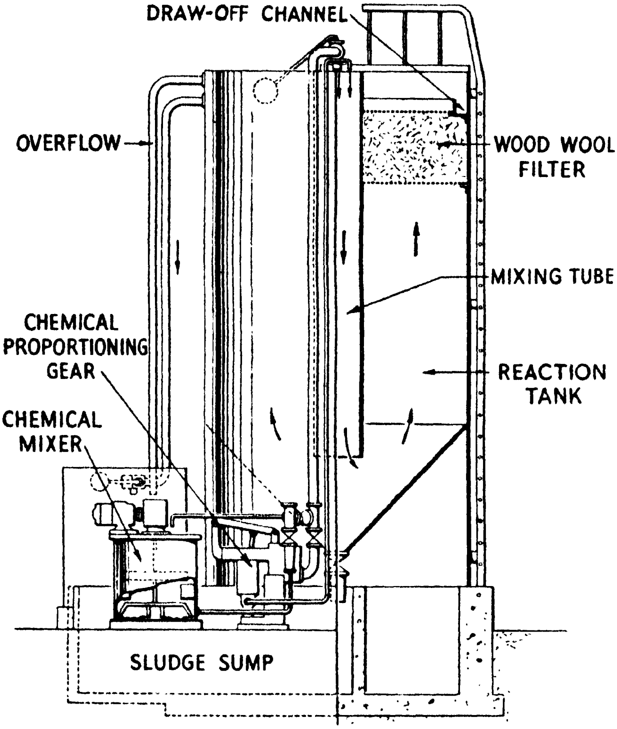
When water is heated, the bicarbonates of calcium and magnesium decompose and deposit carbonates. This deposit forms when water containing temporary hardness is heated to about 160° F., and it therefore occurs in preheaters as well as in boilers. Salts responsible for permanent hardness (mainly sulphates) do not deposit on simple boiling, but in a boiler they become concentrated in the water and eventually crystallise out to form a thick hard scale. The presence of silica in the water may also be harmful as thin hard scales of calcium and magnesium silicates may also be formed, or at high boiler pressures silica may be carried over with the steam, with the formation of almost pure silica deposits on turbine blades.

Corrosion in boilers may be due to dissolved gases, such as oxygen and carbon dioxide, and possibly also indirectly to small quantities of free ammonia, and also to the decomposition of unstable salts such as magnesium chloride and nitrate, which break down under boiler conditions to give free acids. Caustic soda in boiler water may concentrate at temperatures encountered in boiler operation to cause intercrystalline cracking of boiler plates in the rivetted areas under conditions of stress, this type of localised corrosion attack being termed " caustic embrittlement " (Hamer and Colbeck, 1944).

The soluble sodium salts present in the feed water concentrate in the boiler water to a point when foaming and priming will occur, resulting in the " carry-over " of salts and water in the steam causing fouling of superheaters and turbines. The presence of sludge increases the tendency to priming, and the sludge itself will bake on the heating surfaces.

Oil contamination of boiler feed water can have a very serious effect as a result of the oil adhering to metal surfaces and causing overheating. The oil also promotes foaming.

Treatment of Make-up Water. ***Lime-soda process.*** In this process both temporary and permanent hardness is removed from water by the addition of sufficient hydrated lime and sodium carbonate to precipitate the calcium salts as calcium carbonate and the magnesium salts as magnesium hydroxide. If the process is carried out at temperatures of 160° F. or higher, the hardness can be reduced to a very low figure, *e.g.* of the order of 10 parts per million, but in the cold the process is less efficient. Sodium aluminate is used as an additional reagent for waters containing appreciable quantities of magnesium salts, as it coagulates the finely divided precipitate of magnesium hydroxide into large flocs. The lime is added to the water as a " milk ", in which the other reagents are also dissolved, the quantities being accurately computed for the hardness and volume of the water to be treated, with the allowance of a slight excess. A period of 2 to 3 hr. is allowed for the bulk of the precipitate to settle, the remainder being removed by filtration. A diagrammatic arrangement of a lime-soda softening plant with chemical proportioning gear is shown in Fig. WB 1. Incomplete precipitation leading to delayed deposition in pipe lines and boilers may be diminished by " seeding " the mixture of water and reagent with preformed slurry. A combination of the zeolite process of softening with lime softening (Walker, 1948), however, will eliminate " after precipitation " of calcium carbonate and at the same time produce a water having zero hardness and controlled alkalinity. A " stabiliser " unit follows the filter of the lime-soda softener, the " stabiliser " containing carbonaceous zeolite in the spent condition to catalyse the completion of the lime-bicarbonate reaction and to adsorb excess lime. Any residual temporary and permanent hardness may then be removed in a further



[*By courtesy of Dairy Industries Ltd.*

FIG. WB 1.—*Diagram of a lime-soda softening plant with chemical proportioning gear.*

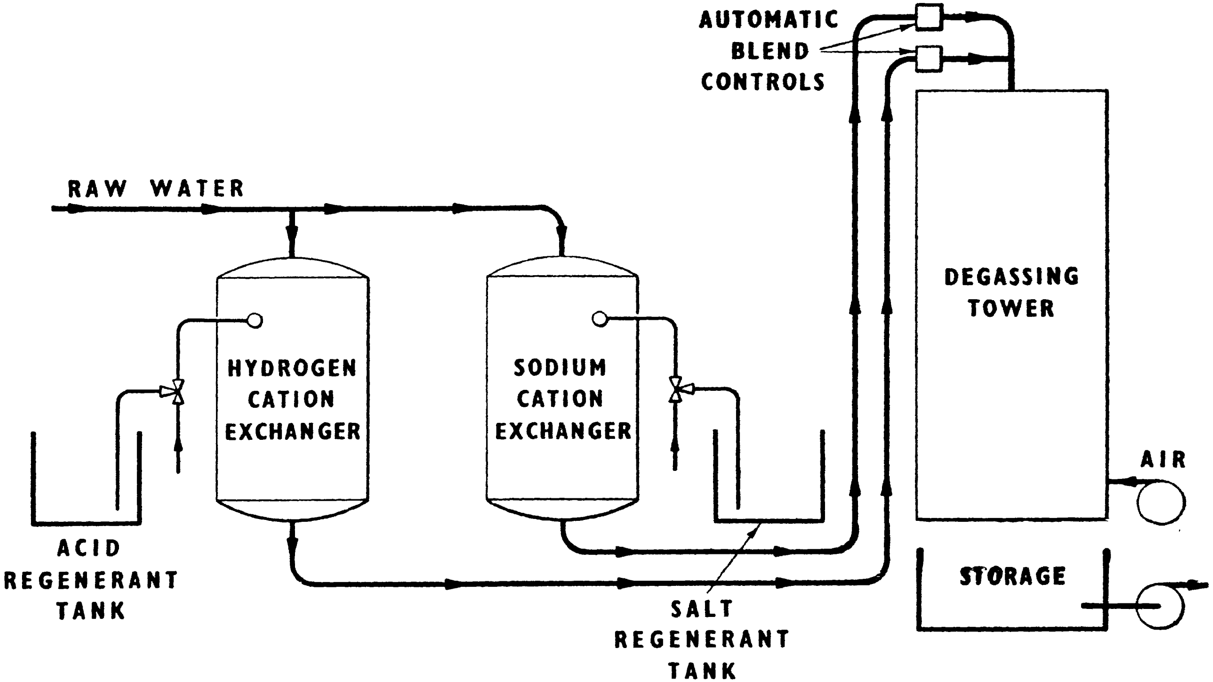
unit employing carbonaceous zeolite as an ordinary base exchange softener. As the base exchange unit will remove permanent hardness, soda may be dispensed with in the lime-softening stage. A further development of this process has been the combination of the filter, stabiliser, and base exchange softener in a single carbonaceous zeolite unit. Water treated by this process has zero hardness, alkalinity to phenolphthalein, nil, alkalinity to methyl orange, 10 to 15 parts per million, and *p*H value 7·5 to 8·0.

Base-exchange or zeolite softening. The base-exchange or zeolite process of softening water has long been used for domestic and industrial purposes, and depends on the property possessed by certain sodium aluminosilicates of exchanging their sodium for the calcium and magnesium associated with the hardness salts in the water. Since the hardness salts are converted to the corresponding sodium salts, there is no reduction in the total dissolved solid content of the water but in fact a slight increase. The zeolites in commercial use comprise natural glauconites, treated clays, and synthetic products produced from sodium aluminate and sodium silicate. The water is passed through a bed of the material at a controlled rate of flow, and after exhaustion the bed is regenerated for further use by treatment with a solution of common salt when the calcium and magnesium of the zeolite are again replaced by sodium. Fig. WB 2 is a perspective view of a base exchange softener arranged for fully automatic control.

Carbonaceous zeolites are cation exchange materials containing little or no silica, and as they are resistant to acids, they may be regenerated with acid as well as with salt. They are prepared by treating carbonaceous substances such as coal, peat or lignite, with fuming sulphuric acid. When regenerated with brine they yield a sodium compound with properties similar to the silicious base exchange zeolites, and when regenerated with acid they yield the corresponding hydrogen compound. Both the sodium and hydrogen state carbonaceous zeolites also possess the property of removing free ammonia from water by ion exchange. Ammonia is believed to play a role in the corrosion of boiler tubes, and since its high solubility in water precludes its complete removal in deaeration, its removal by ion exchange assumes importance. The normal regeneration of the carbonaceous zeolite with acid or salt also removes the ammonia.

The zeolite process has several advantages. The plant occupies less space than with lime-soda plant, and can be fully automatic in operation. It yields a water with a hardness of less than 5 parts per million and provides no sludge-disposal problem. On the other hand, there is no reduction of dissolved solids, dissolved carbon dioxide is not removed and corrosive action may be increased. Water should be freed from iron and from suspended and colloidal matter, particularly oil, before treatment, as these materials are detrimental to the action of the zeolite.

H-ion blend process. It is possible to remove bicarbonates from water other than by lime softening with its large size plant and sludge disposal problem, by blending part of the water treated in a H-ion cation exchange unit with the remainder of the water softened by an ordinary base exchange softener. The free acids in the H-ion effluent are neutralised by sodium bicarbonate in the base exchange effluent with the production of carbon dioxide which is removed by degassing. The correct proportions of water to pass through the H-ion and base exchange units are determined by (1) the alkalinity of the raw water, (2) the free acids contained in the H-ion effluent which depend on the sulphates, chlorides and nitrates in the raw water, and (3) the alkalinity desired in the final mixed effluent. Simple automatic rate-of-flow controls maintain a constant ratio between the effluent flow rates so as to obtain the desired alkalinity in the final mixed effluent or, superimposed on these flow controls, there may be a control related to the *p*H value of the final mixed effluent. The diagrammatic arrangement of an H-ion blend plant is shown in Fig. WB 3.



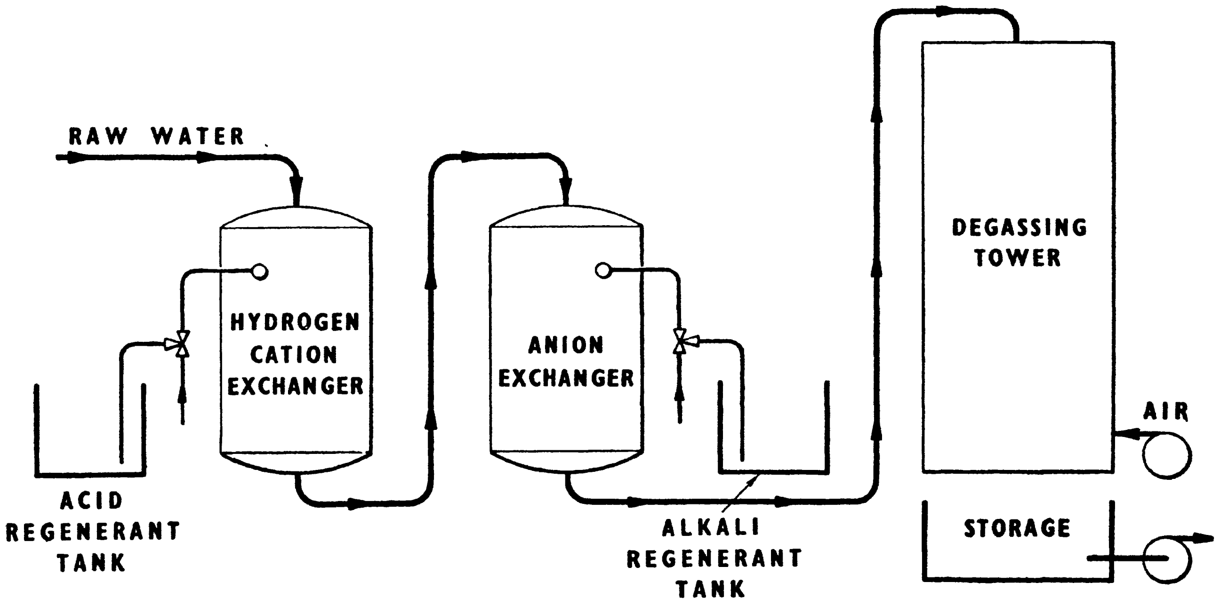
[By courtesy of Dairy Industries Ltd.

FIG. WB 3.—*General diagrammatic arrangement of a type H-Ion blend plant.*

Evaporation. With increasing pressures and temperatures ordinary methods of softening boiler feed water become unsatisfactory, as the need for water containing less and less dissolved solids becomes necessary. With modern evaporator plant distilled water can be produced at any temperature up to 212° F., with a total dissolved solid content not exceeding 3 parts per million, and a dissolved oxygen content not exceeding 0·02 ml. per litre. Evaporation by vapour compression has the effect of increasing the output of distilled water per lb. of steam. In vapour compression evaporators the expansive force of high-pressure live steam is used to compress the vapour of evaporation, so that when the mixture is discharged into a heating chamber its temperature is raised to give the temperature head required for evaporation. Economy of steam consumption is obtained with multiple effect evaporation. In thermal circulation evaporators, the water to be evaporated enters, after suitable preheating, the conical base of a nest of vertical tubes with a large ebullition chamber mounted above. A rapid natural circulation is maintained in the main nest of tubes, the large central tube allowing the return circulation of the unevaporated water to the lower cone. The large ebullition chamber is fitted with a specially designed deflector to ensure purity of the vapour produced. To prevent scale formation on the heating tubes it is desirable that water softened by the processes previously described should be used.

Deionisation. Water of the highest quality for feed to high-pressure boilers may be obtained by the process of deionisation, as an alternative to heat distillation. Adams and Holmes (1935) found that certain tannin resins (cation exchangers), when regenerated with dilute acids, would replace metal ions or cations with hydrogen ions, whereby the salts are converted to the corresponding acids. Adams and Holmes also discovered that resins (anion exchangers), produced from organic substances such as *m*-phenylenediamine by condensation with formaldehyde, would adsorb mineral acids from dilute solutions, and thus it was possible to remove all ionisable salts from aqueous solutions by passage through beds of cation and anion exchange materials arranged in series (Kunin and Meyers, 1950). The cation exchange materials used in deionisation processes are either the " carbonaceous zeolites " already described, or synthetic resins characterised by phenol-formaldehyde, sulphonic acid derivatives. Anion exchangers are synthetic resins made from either aromatic or aliphatic amines by condensation with formaldehyde. In the deionisation process the anion exchange materials are regenerated with an alkali such as sodium carbonate. The water leaving a pair of cation and anion exchange units contains carbon dioxide which can be removed by degassing, and silica (a source of hard deposits in boilers) which is not removed by the normal weakly basic anion exchange materials. Strongly basic anion exchange resins have been developed, however, which remove silica as a third stage in the deionisation process or the silica may be removed by the weakly basic anion resin by a special procedure involving first the conversion of silica to fluosilicic acid and its adsorption by the anion exchanger. The diagrammatic arrangement of a simple, two-stage deionisation plant is shown in Fig. WB 4. The latest development in deionisation is, however, the use of mixed beds of cation and anion exchange materials for complete deionisation (Kunin and Meyers, 1950).

Colloidal and phosphate treatments. Where external softening is not available, some form of internal treatment, such as admission to the boiler of colloids such as starches or tannins, is often adopted. The colloids tend to prevent scale deposition by absorbing the particles or mineral matter and preventing their agglomeration into adherent scale. Frequently, other chemicals such as caustic soda, sodium carbonate and sodium phosphate are used with the colloid to effect a partial softening in the boiler itself. This system has been quite successful where properly operated and controlled. It should be emphasised that the object of any boiler water conditioning is to produce a soft mobile sludge which may be removed by blowing down the boiler.



[*By courtesy of Dairy Industries Ltd.*

FIG. WB 4.—*General diagrammatic arrangement of a deionisation plant.*

An example of the effect of different treatment processes on the quality and content of salts dissolved in water is shown in Table WB I, together with the approximate cost of treatment in respect of the chemicals employed.

It will be seen that softening by the lime-soda, lime-zeolite, and H-ion blend processes reduces the dissolved solids by 20 to 25 per cent., the reduction being greater the higher the temporary hardness. Softening by the base exchange process, however, results in a slight increase in the dissolved solids, and this will be greater the higher the content of magnesium salts. Also the temporary hardness is converted to sodium bicarbonate (expressed in Table WB I as sodium carbonate) which, decomposing in the boilers to carbon dioxide and caustic soda. may result in corrosion. The effect of deionisation is to remove substantially all the salts from the water.

TABLE WB I

EFFECT OF TREATMENT PROCESSES ON DISSOLVED SALTS IN WATER

(Results in parts per million)

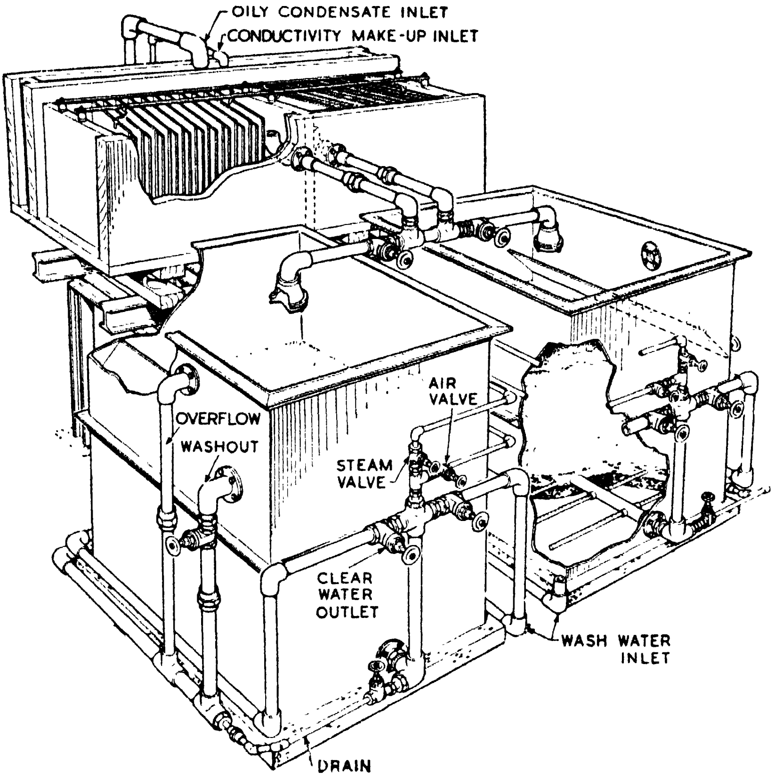
Water resulting from treatment by

Chemical constituent	*Raw water*	*Lime/soda*	*Lime/ zeolite*	*H-ion blend*	*Deionisation*	*Base exchange*
$CaCO_3$.	182·5	30·0	Nil	Nil	Nil	Nil
$CaSO_4$.	3·4	Nil	Nil	Nil	Nil	Nil
$MgSO_4$.	48·0	Nil	Nil	Nil	Nil	Nil
Na_2SO_4 .	276·9	337·3	337·3	337·3	Nil	337·3
NaCl . .	94·8	94·8	94·8	94·8	Nil	94·8
Na_2CO_3 .	Nil	20·0	17·5	Nil	5·8	215·5
NaOH .	Nil	10·0	Nil	Nil	Nil	Nil
Total solids	605·6	492·1	449·6	432·1	5·8	647·6
Cost of treatment (*pence per* 1000 *gal.*) . .		2·4	3·1	6·9	23·7	4·1

Treatment of Condensate. ***De-oiling.*** Condensate derived from steam-driven plant or derived from steam used for process work frequently contains traces of lubricating oil in the form of emulsified particles. As already mentioned, oil contamination of boiler feed water can have a very serious effect, as a result of the oil adhering to boiler plates and tubes causing overheating. Whilst the larger particles of oil can be removed from condensate by mechanical separators, these will have no effect on the smaller particles which must be coagulated before removal is possible.

Coagulation by chemical means involves the use of sulphate of alumina, soda ash, etc., added to the condensate by special proportioning apparatus, in doses large enough to produce a bulky floc to entrap the oil. The floc is allowed to settle in specially designed tanks and the condensate is then filtered through sand, anthracite or wood wool. An appreciable addition of soluble salts to the condensate results, however, from this treatment and, moreover, the costs are high.

An alternative method of coagulating the oil consists of passing a direct current across plate type electrodes between which the condensate flows. An induced charge passes between the electrodes causing the production, electrolytically, of ferric hydroxide which coagulates the emulsified oil particles. The condensate is then filtered through anthracite. The arrangement of an electrical de-oiling plant, for the removal of emulsified oil from condensate, is shown diagrammatically in Fig. WB 5.



[*By courtesy of Dairy Industries Ltd.*

FIG. WB 5.—*Perspective view of an electrical de-oiling plant for treatment of steam condensate.*

Conditioning. It may be desirable to treat returned condensate with caustic soda to prevent feed line corrosion.

Treatment of Feed Water. ***Removal of dissolved gases.*** Dissolved oxygen and carbon dioxide in boiler feed water are the most frequent causes of boiler corrosion. Their removal is usually carried out by vacuum or pressure deaeration whereby the water is sprayed into a chamber, together with steam if the temperature of the water is less than 130° F., and the gases given off by atomisation of the water are removed from the vessel by means of a steam-operated ejector. The oxygen content of the water is reduced to less than 0·02 ml. per litre.

Oxygen can also be removed chemically from the feed water by means of the addition of sodium sulphite, and carbon dioxide by means of caustic soda, but the dissolved solid content of the feed water is raised considerably thereby.

Conditioning. After deaeration of the feed water it is usual to add a small dose of sodium sulphite or suitable tannins to remove the traces of oxygen, and caustic soda to remove the traces of carbon dioxide. It is desirable that there should be a sulphite residual in the boiler water of 20 to 30 parts per million, and that the sodium sulphate/caustic soda ratio should be greater than 2·5 : 1, sodium sulphate being an inhibitor of caustic embrittlement. The caustic soda dose should adjust the *p*H value of the feed water to above 7·5. With water-tube boilers it is usual to slug feed periodically into the boiler drum a dose of trisodium phosphate to precipitate any residual hardness which might leak through from the treatment plant, and also emulsified oil. A phosphate residual of 30 to 50 parts per million as PO_4 is usually maintained for this purpose.

Boiler Blow-down. If the dissolved solids in the boiler water are allowed to exceed a certain concentration dependent on the type of boiler and operating pressure, foaming and priming may occur and also corrosion and the formation of hard deposits. In Table WB 2 recommended boiler-water densities, which should not be exceeded, are given for different types of low-pressure boilers.

TABLE WB II

APPROXIMATE MAXIMUM PERMISSIBLE BOILER-WATER CONCENTRATIONS FOR DIFFERENT TYPES OF LOW-PRESSURE BOILERS

(Ministry of Fuel and Power)

Type of boiler	*Boiler concentration parts per million*
Lancashire and Cornish	14,000 to 17,000
Economic	3500 to 4250
Vertical	2000 to 4250
Water tube (low pressure)	4250 to 10,000
Locomotive	2000 to 3500

The boiler-water densities may be maintained at these levels by intermittent blowing-down, using hand control, but this method wastes heat and is erratic.

Continuous blow-down systems involve the use of a needle valve or a control orifice fitted to the blow-down of the boiler, whereby a continuous bleed-off takes place at the prescribed and controlled rate. The blow-down is led to a flash chamber in which low-pressure steam is flashed off and is returned to the boiler feed tank and the discharge to waste is passed through a coil in the feed tank. In this way 80 to 95 per cent. of the heat contained in the blow-down may be conserved.

Boiler blow-down is usually expressed as a percentage of the boiler evaporation or quantity of boiler feed water. The amount of blow-down required to maintain the boiler-water concentration at a given level is estimated as follows:

A = blow-down as a percentage of boiler evaporation;

B = total dissolved solids in feed water;

C = allowable concentration of dissolved solids in boiler water, then

$$A = B/C \times 100.$$

In calculating the total dissolved solids in the feed water, no account should be taken of the precipitable temporary hardness.

Boiler-Water Testing (*BS*, 1949). Whilst routine analysis of boiler water for alkalinity, total dissolved solids, etc., is essential for the correct control of boiler-water conditions, it is usually found that once control has been established the rate of blow-down may be regulated by regular determinations of boiler-water concentration alone.

Boiler-water samples (*BS*, 1946) must be cooled below atmospheric boiling point before being drawn off for test in order to avoid false concentrations resulting from partial flashing into steam.

Daily tests for concentration in boiler water may be made by hydrometer or by an electrical conductivity meter, and the results should be correlated with the total dissolved solids determined gravimetrically at less frequent intervals. For concentrations less than 2000 to 3000 parts per million the conductivity method of measurement is preferable, but for higher concentrations the hydrometer may be used. Either of these methods of measurement is liable to errors owing to variation in the composition of the boiler water, but the readings obtained, used in conjunction with the total dissolved solid content of the boiler water determined gravimetrically, form a convenient basis on which to control the blow-down quantity.

Hydrometer tests may be made with British Standard hydrometers or with metal hydrometers. They are calibrated in grammes per millilitre at 20° C., and if used at any other temperatures, must be corrected to obtain the density of the water at 20° C.

Boiler-water conductivity is usually quoted in dionic units, and water having an electrical resistance of 1 megohm per centimetre cube at 20° C. is said to have a conductivity of 1 dionic unit or 1 micromho. Conductivity is usually measured at room temperature, and unless the conductivity instrument is fitted with a temperature-compensating device, correction must be made to obtain the conductivity at the standard temperature of 20° C. The ratio of conductivity (in dionic units at 20° C.) to total dissolved solids (in parts per million) in an aqueous solution of sodium chloride is 2 : 1, and in an aqueous solution of typical boiler-water salts the ratio is of the order of 2·5 : 1, but this figure is, however, liable to error of plus or minus 20 per cent., depending on the balance of salts in the water, and should be checked against gravimetric determination of total dissolved solids.

Refs.: Adams and Holmes (1935), *JSCI*, **54**, 1 (Synthetic resins); *B.S. Specification*, No. 1328 (1946) (Methods of sampling water used in steam generation); *B.S. Specification*, No. 1427 (1949) (Tests for water used in steam generation); Hamer and Colbeck (1944), *CI*, pp. 163-65 (Caustic embrittlement in boilers); Kunin and Meyers (1950), *Ion Exchange Resins*, New York; Matthews (1951), *Boiler Feed Treatment*, London; Ministry of Fuel and Power, *Fuel Efficiency Bulletin*, No. 35 (Blow-down); Nordel (1951), *Water Treatment*, New York; Walker (1948), *CI*, pp. 695-97 (Lime-zeolite process).

WATERY FOODS, EFFECT ON MILK COMPOSITION. Feeding such foods does not lower the solids of the milk or affect the freezing-point, although some practical men believe so. With-holding of water followed by excessive drinking may affect the freezing point. *See* Composition of milk; Fallacies; Feeding; Freezing point.

WATT. The scientific unit of power. Defined as ampères × volts in electrical terms.

WEATHER, EFFECT OF ON MILK COMPOSITION. Bad weather and extremes of temperature may lower the yield. *See* Composition, factors affecting.

WEIGHT. The term " weight " is used in two senses : (i) the quantity of matter in a body (this is strictly speaking *mass*) ; (ii) the gravitational pull of a body. Weight is, strictly speaking, the force exerted by gravity on a body, and is given by the mass of the body (*q.v.*) × g, the acceleration of gravity. Since g varies slightly in different parts of the world, the weight of a body depends to a very small extent on its locality.

Weight = mass × gravitational pull.

WEIGHTS AND MEASURES, TABLES AND EQUIVALENTS.

(Figures in brackets are reciprocals.)

Length

1 inch = 2·54 centimetres (0·3937)
1 foot = 30·48 centimetres (0·0328)
1 yard = 0·9144 metre (1·094)
1 mile = 1·609 kilometre (0·6214)

WEIGHTS AND MEASURES (LEGAL)

Area

1 acre = 4840 square yards
1 square mile = 640 acres

Volume

1 cubic inch = 4·614 fluid drams (0·2167)
= 0·5767 fluid ounce (1·734)
= 0·02884 pint (34·68)
= 16·39 cubic centimetres (0·06102)

1 cubic foot = 996·6 fluid ounces (0·001003)
= 49·83 pints (0·02007)
= 6·229 gallons (0·1605)
= 28·32 litres (0·03531)

1 cubic yard = 168·2 gallons (0·005946)
= 0·7645 cubic metre (1·308)

1 pint = 20 fluid ounces = 160 fluid drams = 9600 minims
= 568·2 cubic centimetres (0·00176)
= 0·5682 litre (1·76)

1 gallon = 4·546 litres (0·22)
= 277·5 cubic inches

1 gallon (U.S.A.) = 231 cubic inches or 0·82 Imperial gallon

Weight

1 dram = 1·772 grams (0·5644)
1 ounce = 28·35 grams (0·03527)
1 pound = 453·6 grams (0·002205)
1 hundredweight = 50·8 kilograms (0·1968)
1 ton = 1016 kilograms (0·00098)
1 kilogram = 2·2046 pounds

Weight and Volume

1 cubic foot water = 62·3 pounds
= 0·556 hundredweight
1 pound water = 27·746 cubic inches
= 0·4536 kilogram
1 hundredweight water = 1·798 cubic feet
= 11·2 gallons
1 ton water = 35·967 cubic feet
= 224 gallons
= 1000 litres (approx.)
= 1 cubic metre (approx.)

Heat

1 British thermal unit = 252 calories (0·00397)

1 kilowatt hour = 3413 British thermal units (0·000293)
= 860,000 calories (0·00000116)

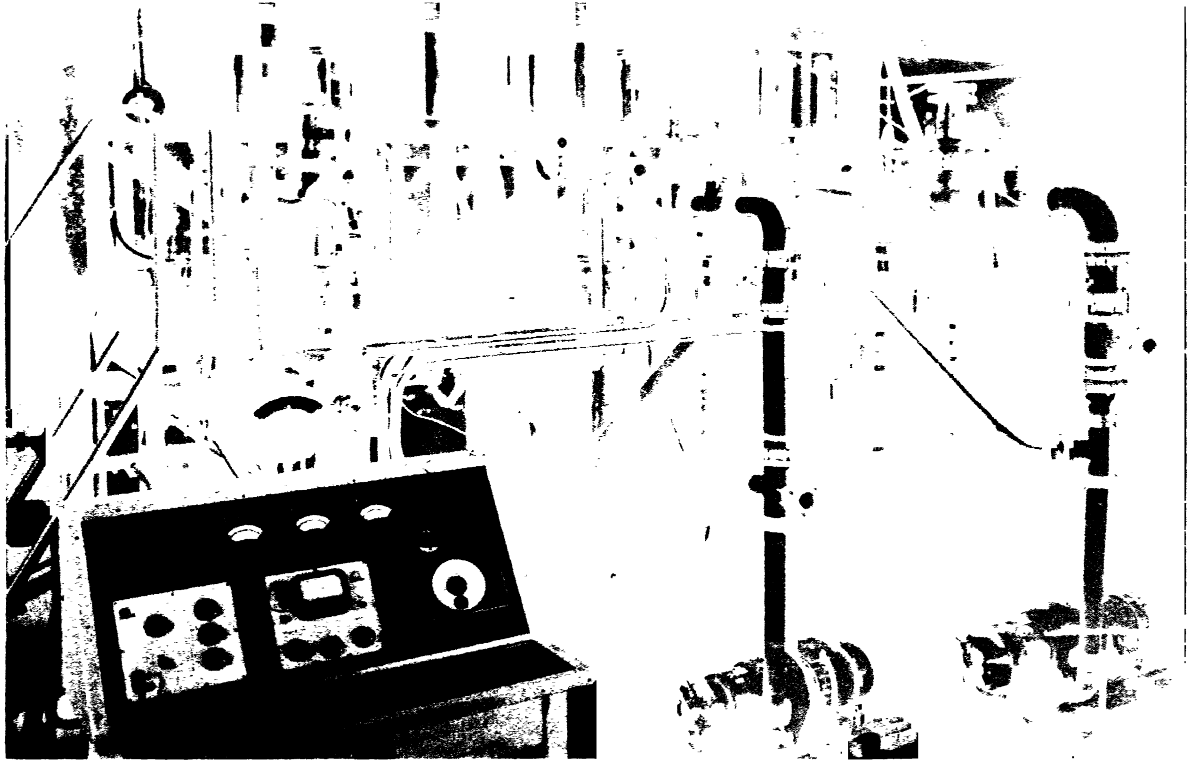
Specific Gravity

$$\frac{\dfrac{\text{Degrees Twaddell}}{2} + 100}{100} = \text{specific gravity}$$

WEIGHTS AND MEASURES (LEGAL).

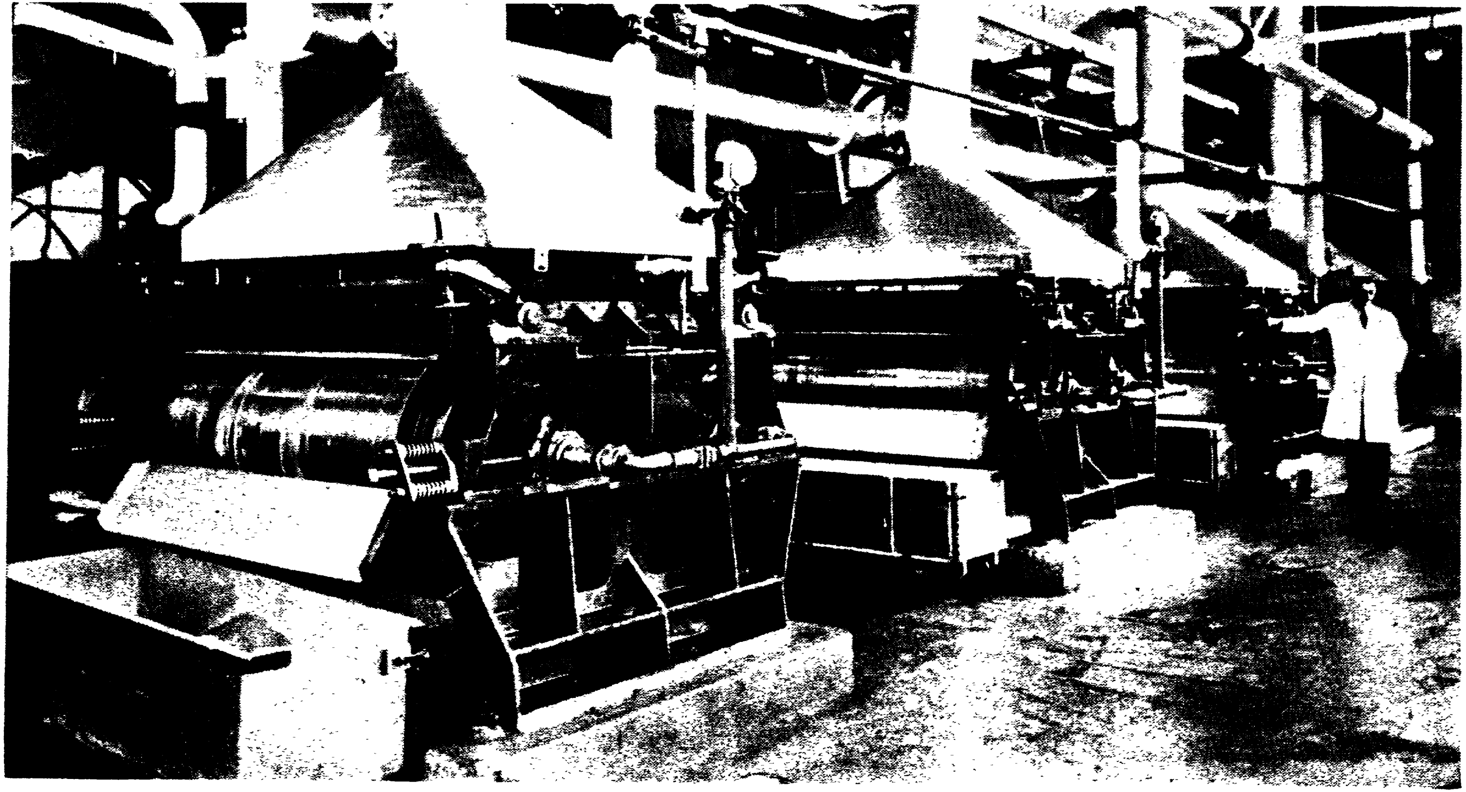
Refs.: Bd. Trade (1951), *Rep. Ctte. on Weights and Measures Legislation*, H.M.S.O.

WENSLEYDALE. *See* Cheese, p. 203.



[By courtesy of Dr. E. Wegelin.

FIG. Wh 1.—*Apparatus for the Electro-dialysis of Whey.*



[By courtesy of the Milk Marketing Board

FIG. Wh 2.—*Roller Whey Drying Plant.*

WERNER-SCHMID METHOD. A method for estimating fat similar to the Röse-Gottlieb but using hydrochloric acid to separate the casein from the fat. *See* Fat.

Ref.: Richmond.

WESTPHAL BALANCE. An apparatus for measuring the specific gravity of a solid or a liquid by determining the loss of weight when a solid is weighed immersed in a liquid.

WET MILKING. A method of milking in which the fingers are smeared with milk to lubricate their movement against the teat. It is a thoroughly unhygienic and undesirable practice, but is still prevalent, especially in the more backward dairy counties. *See* Clean milk production; Management of dairy cattle; Milking machines.

WETTING POWER. *See* Detergents.

WHALE MILK. *See* Mammals.

WHEY. Although whey has been a by-product of cheesemaking for thousands of years, the whey problem did not really arise until factory cheesemaking came into being. For a factory converting, say, 10,000 gal. of milk into cheese daily, the problem of whey disposal is of overwhelming importance. The following summarises the known methods of dealing with whey from the factory:

(i) Unchanged: (1) return to the farmer, (2) set up pig farming, (3) use for whey silage, (4) convert to whey beverages.

(ii) Drying: (1) whey paste, (2) whey powder, (3) extraction of lactose.

(iii) Boiling: (1) albumin cheese.

(iv) Microbiological utilisation: (1) fermentation to lactic acid, (2) fermentation to alcohol, (3) use as medium for yeast for cattle food.

Whey is usually separated to remove the fat at the factory.

Nutritive value. People in the dairy industry are so accustomed to think of whey as a watery by-product fed to pigs, that its value as a human food is often overlooked. We produce annually some 100,000,000 gal. of whey, containing 50,000,000 lb. of milk-sugar, sufficient to provide ¼ lb. per week for every person in the country for a month.

Further, whey contains nearly half the solids of the original milk, and is, in fact, more than half as rich in solids as milk. It is particularly rich in calcium and vitamin B_2, in which the diets of certain sections of the community may be deficient.

Utilisation of whey without processing. Returning whey to the farmer appears to be the obvious way of dealing with the by-product. There are, however, a number of difficulties to be considered. For a farmer to take whey means, in effect, keeping pigs, and this may not be desirable for more than one reason. Secondly, in factory making, the problem of transport is not so simple as it seems. Carriage of whey in milk churns is prohibited by law in some countries, and, even when permitted, is undesirable, as the souring whey is destructive for churns.

As the return of whey from raw milk cheese may result in the introduction of tubercle bacilli and other harmful bacteria to farms, it is recommended that all whey should be pasteurised before being sent away. This is conveniently done in a heat exchanger or even by using a steam pipe directly introduced into the churns. The whey should be raised to a temperature of at least 170° F., and afterwards cooled if possible. For the reception of whey on T.T. farms such treatment is compulsory.

Farmhouse-making now constitutes very little of our total cheesemaking, and although it is desirable that a first-class food like whey should be used as human food, the trouble of collection from farms does not warrant interfering with the traditional method of disposal.

It is, of course, possible for cheese factories to engage in pig farming, but there are difficulties in large-scale pig farming. Factories now usually dry their whey or send it away to be dried elsewhere. Much of this is used for animal feeding, e.g. calf starter. As the efficiency of producing animal foods is at the most about 20 per cent., a loss of some 80 per cent. in the feeding, as much dried whey should be used for human food as possible.

Whey Beverages. This is as yet an undeveloped line of attack on the whey problem. If whey were separated and pasteurised directly after drawing from the vat, treated with the usual sugar citric-tartaric acid mixture, suitably flavoured, carbonated and bottled, it would make a very attractive and highly nourishing drink. In hot weather it would provide a pleasant alternative to ice-cream sodas. The drink would be particularly suitable for those who could not drink milk itself on account of digestive trouble. Whey can be demineralised by electro-dialysis (Fig. Wh 1).

Whey Silage. This is a method that is not used as it could be. It is, for instance, illogical for farmers to buy imported molasses when they could use a perfectly good carbohydrate-rich liquid available at their door-step. Cheesemaking farmers would be well advised to go into the question of utilising some of their whey for this purpose. Thus whey can be used for diluting molasses to avoid a common fault of whey silage (too much moisture), and effect a considerable economy in molasses.

Drying Whey. Practically all factory whey is now dried, either directly on rollers (Fig. Wh 2), or by preliminary condensing and spray drying. The best dried whey is a product of good appearance, a fine white powder and slightly sweet. It is used now for bread, etc., and by inversion of the lactose (which constitutes some 70 per cent. of dried whey) to the sweeter dextrose, a very useful and cheap sweetening agent could be obtained. Whey paste (about 70 per cent. solids) will keep several months, while whey powders will keep almost indefinitely if kept dry. A common trouble under certain conditions (*e.g.* sending whey away for drying, or holding it over because of the small capacity of the drier) is souring. Neutralisation will not solve the problem, because sodium lactate is hygroscopic, *i.e.* does not dry easily, and if lime is used instead of soda, calcium lactate can also be a source of faulty drying. The best solution is H.T.-S.T. pasteurisation immediately after the whey is run from the vat, followed by cooling to below 60° F. Under emergency conditions, souring can be prevented by the addition of chemical preservatives, *e.g.* formalin (1 in 10,000 to 1 in 20,000) or hydrogen peroxide (1 in 1000 to 1 in 2000 of 20 vol.). This is not legally permissible, but, if adopted, the excess preservative can be destroyed before drying, formalin by the addition of the required amount of hydrogen peroxide, and hydrogen peroxide by adding the necessary amount of formalin. However, in view of the small quantity of formalin used and the instability of hydrogen peroxide, this is not really necessary.

Whey is the source of lactose or milk sugar, not so sweet as dextrose (grape sugar) or sucrose (cane sugar), but used for certain foods and other products.

Whey contains about 0·25 per cent. fat, and this can easily be separated and a very good product, whey butter, made from the cream. The total solids content is about 6·85 per cent. It is customary to separate whey first before it is dried or otherwise treated.

In some countries whey is boiled and the coagulated albumin enmeshed on sticks and a cheese (Ziger) made from it. Alternatively, the albumin can be dried and used as a concentrate for cattle.

Microbiological Utilisation. The simplest procedure under this heading is to ferment the lactose to lactic acid. This is done by the addition of chalk and cultures of *L. bulgaricus* to whey at a temperature of 45° to 50° C. After boiling and filtering, the liquor is condensed and calcium lactate crystallises, from which lactic acid is obtained by the addition of sulphuric acid. Alternatively, by the addition of molasses (to raise the sugar content) whey could be fermented by a lactose-fermenting yeast to alcohol.

A further method could be developed that would solve two problems at once and both use the whey efficiently and separate the dry matter. By addition of inorganic nitrogen to whey and allowing yeast to grow in it under certain conditions, a good yield of sedimenting yeast could be obtained and used for cattle food.

In this process, whey is used as a source of necessary growth factors and sugar for the yeast, which converts the inorganic nitrogen (not available to animals) to organic material that can be used for feeding cattle. The yeast, being heavier than the impoverished whey, sinks to the bottom and so effects a simple gravity separation of the solids in the whey. *See* Cheese ; Pigs.

Refs.: Harding (1925), *Min. Agric. Res. Mon.* 5; Friedel (1948), *M*, **3**, 292 (filtration); Schulz and Fackelmeier (1948), *M*, **3**, 165 (beverages); Schulz and Dracke (1947), *M*, **2**, 276 (fruit-whey beverages); Csiszár (1949), *IDC*, **2**, 131 (specific gravity); Muers and Murphy (1949), *IDC*, **2**, 872 (total solids condensed whey); Aten *et al.* (1949), *IDC*, **3**, 381 (electrodialysis) ; Anäs, 454 (concentration by freezing) ; Higginbottom (1944), *JDR*, **13**, 308 and 324 (flora of whey powder); Crossley and Johnson (1942), *JDR*, **13**, 5 (bacteriology, moisture, and solubility); Waite (1941), *JDR*, **11**, 71 (roller drying); Siman (1953), *DSA*, **15**, 166 (utilisation); Prescott and Dunn.

WHEY, CONCENTRATED. The chief disadvantage of whey as a potential food product is its large water content and tendency to sour rapidly. Condensed whey gives a product of lower water content, and one which will not sour, on account of the increased osmotic pressure. Ordinary condensed whey is prepared by the same method as for condensed milk. The heated whey is condensed in a vacuum pan to a solids content of about 70 per cent. The densities corresponding to various total solids values are given in Table Wh I.

TABLE Wh I

(Whittier and Webb)

THE DENSITY OF CONDENSED CHEESE WHEY OF DIFFERENT PERCENTAGES OF WHEY SOLIDS

Total solids %	*Density at* 115° *F.*		*Total solids* %	*Density at* 115° *F.*	
	°*Be*	*Sp. gr.**		°*Be*	*Sp. gr.**
30	15·6	1·121	54	28·9	1·249
32	16·7	1·130	56	30·1	1·262
34	17·8	1·140	58	31·2	1·274
36	18·9	1·150	60	32·3	1·287
38	20·1	1·161	62	33·4	1·299
40	21·2	1·171	64	34·5	1·312
42	22·3	1·182	66	35·6	1·325
44	23·4	1·192	68	36·7	1·339
46	24·5	1·203	70	37·8	1·353
48	25·6	1·214	72	38·9	1·367
50	26·7	1·226	74	40·1	1·382
52	27·8	1·237	76	41·2	1·397

$$* \text{Sp. gr.} = \frac{145}{145 - {}^{\circ}\text{Be}}.$$

Condensed whey is naturally very rich in lactose. In fact, it is highly supersaturated lactose, and will sometimes start to crystallise before the batch leaves the pan.

Ref.: Whittier and Webb.

WHEY POWDER. Condensed whey usually contains up to 20 to 30 per cent. solids. It is dried by the roller method in this country, although some spray dried whey is also produced. Container or shelf drying is also used in America. The drying of whey is a tricky procedure, and there are a number of patents concerned with it. The difficulties arise from the fact that it is a liquid containing a large amount of lactose and a certain amount of whey-soluble proteins; it is a liquid which sours very rapidly. It is most desirable to have the whey in as sweet a condition as possible for drying, and the addition of a preservative would be useful, although this must not be added if the whey powder is to be used for human food. Neutralisation back to the original *p*H of milk (6·6) is recommended. Sodium bicarbonate is not the best neutraliser for this purpose as sodium lactate is hygroscopic and both lactic acid and sodium lactate tend to burn on the rollers. Either a mixture of lime and sodium carbonate or even lime alone may give better results.

Ref.: Whittier and Webb.

WHIPPING OF CREAM. The effect of whipping is to force tiny bubbles of air into the cream which produce rigid structures with the fat globules and adsorbed proteins at the liquid-air interfaces. In addition, the churning effect results in clumping and the initiation of those stages preceding butter formation. *See* Cream.

Refs.: Mohr and Koenen (1953), *IDC*, **2**, 493.

WHITE BLOOD CORPUSCLES. *See* Leucocytes.

" WHITE HEIFER DISEASE." There is a common belief amongst dairy farmers that a white heifer will not be fertile, and so sterility has come to be associated with whiteness in cows. For this reason the term " white heifer disease " is sometimes used by farmers loosely to denote sterility, but this is only due to the survival of this prejudice. *See* Breeding.

WHITE SCOURS. A disease of calves in which the organism gains access *via* the mouth.

WHITESIDE TEST. A simple presumptive test for the presence of mastitis streptococci in udder-samples. Two ml. N NaOH are added to 10 ml. milk, and the mixture beaten with a glass rod. A viscous mass is formed and later a cherry-red colour develops. *See* Abnormal milk; Mastitis.

Refs.: Whiteside (1939), Can. Publ. Hlth. J., **30**, 44; Murphy (1942), Cornell Vet. **32**, 439, Dunn *et al.* (1943) *JDS*, **26**, 295; Murphy and Hanson (1941), Cornell Vet. **31**, 47; Chu (1949), *JCP*, **59**, 81 (comparison).

WISCONSIN CURD TEST. A test designed to detect milk unsatisfactory for cheesemaking. It is essentially making a miniature, embryonic cheese with the sample of milk. A little rennet is added to the milk at 90° F. and the resultant curd is cut and the whey drained off. The curd is then held at 98° F. and examined at a convenient time. The presence of gas bubbles, taint, sliminess, etc., indicates that the milk would be unsuitable for cheesemaking. *See* Cheese; Coliforms; Stormy fermentation test.

Ref.: Hammer.

WOMAN. *See* Human milk; Mammals.

WOOD, AS MATERIAL IN DAIRYING. Wood as an absorbent material is difficult to clean and should be avoided in dairy work as far as possible. Wood is still used for butter churns and workers as it is superior to metal in not " sticking " to the butter. Metal churns and workers are, however, now being introduced.

WORK. This quantity is measured by the force applied × distance moved. The scientific unit is the erg or joule (10^7 ergs).

WORLD PRODUCTION AND UTILISATION OF MILK. Tables WP I to WP XIII give data reported in *Dairy Produce* (1953) published for the Commonwealth Economic Committee (H.M.S.O.).

Ref.: Kesteven (1952), *JSDT*, **5**, 157.

TABLE WP I—NUMBERS OF COWS IN CERTAIN COUNTRIES

(thousands)

Country	1938	1942	1946	1947	1948	1949	1950	1951	1952
Commonwealth									
United Kingdom . .	3,835	4,199	4,422	4,379	4,490	4,601	4,628	4,476	4,462
Canada	3,730	3,681	3,711	3,697	3,701	3,621	3,609	2,853	3,013
Australia . . .	3,214	3,247	3,025	3,013	3,085	3,159	3,191	3,149	2,974
New Zealand . . .	1,743	1,757	1,662	1,658	1,714	1,747	1,846	1,898	1,906
Union of S. Africa . .	—	—	3,782	3,724	—	—	3,679	3,613	—
S. Rhodesia[1] . . .	240	287	336	339	383	403	382	378	—
Kenya[1]	103	—	307	322	354	375	389	408	—
Irish Republic . . .	1,282	1,206	1,201	1,156	1,134	1,176	1,209	1,189	1,159
Foreign									
U.S.A.	24,466	26,398	26,785	26,098	25,039	24,416	24,573	23,722	23,369
France	8,732	7,358	7,414	7,436	7,609	7,837	8,092	8,424	8,478
Western Germany . .	5,990	—	—	5,241	5,235	5,535	5,734	5,748	5,807
Italy	3,828	3,872	3,000	3,304	3,625	3,812	3,896	—	—
Poland[2]	6,294	—	2,748	3,079	3,647	4,059	—	—	—
Turkey	2,365	2,172	2,442	2,561	2,648	2,656	2,670	—	—
Czechoslovakia . .	2,448	2,289	2,059	2,021	1,861	1,871	1,921	—	—
Sweden	1,912	1,650	1,818	1,808	1,705	1,706	1,679	1,621	1,550
Denmark	1,599	1,415	1,594	1,546	1,572	1,535	1,577	1,584	1,476
Netherlands . . .	1,503	1,274	1,279	1,326	1,324	1,441	1,518	1,533	1,483
Austria	1,223	1,387	1,256	1,188	1,166	1,214	1,263	1,257	1,286
Finland[3]	1,368	1,081	1,221	1,074	1,003	1,029	1,135	1,143	—
Belgium	966	811	776	779	721	820	901	932	952
Switzerland . . .	913	824	815	822	809	839	858	886	912
Hungary	917	—	655	813	838	—	—	—	—
Norway	832	817	801	795	768	769	766	755	711
Japan	178	223	163	159	171	202	213	221	271
U.S.S.R.	22,985[4]	—	—	24,700[5]	—	—	24,200	27,800	29,700
Roumania	—	—	—	—	—	—	—	—	—
Yugoslavia . . .	—	—	—	—	—	2,189	2,336	—	2,267

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[1] European owned only.
[2] Revised Boundary figures.
[3] As at 1 September, with exception of years 1942 and 1945 (1 March).
[4] 1937 figure : includes Latvia—873 ; Lithuania—765 ; Estonia—447.
[5] Estimated.

TABLE WP II

Milk Production in certain Countries, showing Percentages used for Manufacture

(million gal.)

Country	1938	1942	1947	1948	1949	1950	1951	1952
United Kingdom								
Total production[1] .	1,249	1,269	1,450	1,618	1,735	1,887	1,790	1,818
% manufactured .	*31·2*	*12·2*	*9·9*	*12·4*	*12·7*	*17·4*	*12·1*	*15·0*
Canada								
Total production. .	1,536	1,698	1,674	1,624	1,635	1,596	1,595	1,630
% manufactured .	*64·7*	*66·5*	*61·1*	*61·9*	*60·9*	*58·0*	*57·6*	*58·0*
Australia[2]								
Total production .	1,189	1,130	1,168	1,113	1,254	1,205	1,059	1,228
% manufactured .	*86·1*	*82·3*	*79·3*	*79·4*	*79·9*	*79·6*	*75·8*	*78·8*
New Zealand[2]								
Total production .	892	893	908	983	1,011	1,074	1,078	1,143
% manufactured[3] .	*88·8*	*88·6*	*88·3*	*88·7*	*88·3*	*88·7*	*88·8*	*89·2*
United States								
Total production .	10,547	11,817	11,834	11,491	11,852	11,979	11,150	11,176
% manufactured .	*55·8*	*55·7*	*50·7*	*48·7*	*49·6*	*48·5*	*49·3*	*48·6*
France								
Total production .	3,094[4]	1,862	2,204	2,385	2,555	2,874	3,276	3,125
% manufactured .	*52·9*	*51·3*	*47·0*	*46·8*	*48·6*	*51·7*	*53·3*	*52·7*
Western Germany								
Total production . .	3,211[5]	—	—	—	2,422	2,975	3,247	3,385
% manufactured .	*61·3*	—	—	—	*60·0*	*55·4*	*54·8*	*51·8*

[1] Total sales off farms.

[2] Twelve months ending 30 June of following year.

[3] Includes losses in home separation.

[4] 1939 figure.

[5] 1935-38 average.

TABLE WP II—*(contd.)*

Country	1938	1942	1947	1948	1949	1950	1951	1952
Italy								
Total production .	1,451	1,211	1,152	1,376	1,487	—	1,809	1,725
% manufactured .	*47·6*	*47·2*	*45·9*	*46·3*	*48·1*	—	*48·4*	—
Netherlands								
Total production .	1,140	667	777	960	1,146	1,225	1,216	1,199
% manufactured .	*73·6*	*63·2*	*44·6*	*51·7*	*57·9*	*61·0*	*62·4*	*62·9*
Sweden								
Total production .	997	781	962	942	995	1,049	1,022	978
% manufactured .	*58·7*	*53·5*	*57·6*	*56·8*	*58·8*	*59·7*	*59·8*	*58·1*
Denmark								
Total production .	1,160	714	879	863	1,040	1,158	1,120	1,070
% manufactured .	*84·6*	—	*75·7*	*77·4*	*80·9*	*82·0*	*80·7*	*78·7*
Switzerland								
Total production .	580	484	441	489	522	551	574	576
% manufactured .	*45·7*	*37·3*	*38·0*	*38·4*	*39·5*	*42·7*	*43·7*	*42·9*

TABLE WP III—UTILISATION OF WHOLE MILK IN CERTAIN COUNTRIES (million gal.)

Country	*Total production*	*Butter*	*Cheese*	*Canned milk*	*Dried milk*	*Other milk products*	*Ice cream*	*Liquid milk* [1]
United Kingdom [2]								
1938 . . .	1,249	113	98	82	15	80	1	860
1948 . . .	1,618	44	60	42	53	2	—	1,417
1951 . . .	1,790	23	103	48	36	7		1,573
1952 . . .	1,818	33	131	61	34	12		1,546
Canada								
1938 . . .	1,536	814	136	30		—	14	542
1948 . . .	1,624	793	102	76		—	35	618
1951 . . .	1,595	691	103	83		—	44	674
1952 . . .	1,630	735	80	84		—	48	683
Australia [3]								
1938-39 . . .	1,189	925	65	33			—	166
1948-49 . . .	1,213	781	94	82			—	250
1951-52 . . .	1,059	638	87	78			—	256
1952-53 . . .	1,228	780	102	86			—	260
New Zealand [3]								
1938-39 . . .	892	600	172		6		—	114 [4]
1948-49 . . .	983	650	195		16		—	122 [4]
1951-52 . . .	1,078	755	185		17		—	121 [4]
1952-53 . . .	1,143	786	208		25		—	124 [4]
United States								
1938 . . .	10,547	4,355	704	485	20	—	321	4,662
1948 . . .	11,491	2,926	1,061	791	126	54	640	5,893
1951 . . .	11,150	2,842	1,120	681	97	73	680	5,657
1952 . . .	11,176	2,830	1,135	630	70	70	702	5,739

[1] Includes milk consumed on farms, milk fed to animals, cream, and ice cream where no separate figures are available.

[2] Excludes farm consumption except for farm cheese.

[3] Years ending 30 June.

[4] Includes losses in farm separation.

TABLE WP III (*contd.*)

Country	*Total production*	*Butter*	*Cheese*	*Canned milk*	*Dried milk*	*Other milk products*	*Ice cream*	*Liquid milk*
France								
1939	3,094	1,099	509	28				1,458
1948	2,385	831	261	25				1,268
1951	3,276	1,151	541	56				1,528
1952	3,125	1,092	507	47				1,479
Sweden								
1939	1,019	517	80	2				420
1948	942	468	54	12				408
1951	1,022	516	86	8				412
1952	978	451	94	24				409
Switzerland								
1938	580	130[5]	130	5				315
1948	489	60[5]	120	7				302
1951	574	119[5]	123	9				323
1952	576	102[5]	136	9				329
Western Germany . .			107					
1935-38 average .	3,211	1,819	107	43			—	1,242
1950	2,975	1,413	150	86			—	1,326
1951	3,247	1,533	169	77			—	1,468
1952	3,385	1,488	181	85			—	1,631
Denmark								
1938	1,160	932	44	6			—	178
1948	869	574	78	17			—	200
1951	1,120	764	111	28			—	217
1952	1,070	681	124	36			—	229

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[5] Includes cream and cheese made from skimmed milk.

WORLD PRODUCTION AND UTILISATION OF MILK

TABLE WP IV

ESTIMATED PER CAPUT CONSUMPTION OF LIQUID MILK IN CERTAIN COUNTRIES

(gal.)

Country	1938	1946	1949	1950	1951	1952
United Kingdom	21·1[3]	30·4	33·1	33·8	33·8	33·3
Australia[1]	23·6[4]	29·5	29·7	—	28·4	28·0
New Zealand[1, 2]	40·7[3]	—	47·6	47·8	47·8	47·4
Canada	29·2[5]	40·3	35·2	35·1	40·8	40·2
U.S.A.[2]	32·8	41·3	37·4	37·9	38·3	38·8
Netherlands	30·8	39·8	42·8	41·0	43·8	44·9
Denmark[2]	36·2	41·0	35·5	36·4	36·8	37·0
Switzerland	51·4	47·9	50·6	49·7	48·8	47·1

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[1] Twelve months ending 30 June of following year. [2] Including cream.

[3] 1934-38 average. [4] 1936-39 average. [5] 1939.

TABLE WP V

PRODUCTION OF BUTTER IN CERTAIN COUNTRIES

(thousand cwt.)

Country	1938	1942	1945	1948	1949	1950	1951	1952
Commonwealth								
United Kingdom[1]	400	200	160	170	208	330	112	144
New Zealand[2]	3,107	2,893	2,596	3,388	3,438	3,688	3,875	4,049
Australia[2]	4,070	3,425	3,007	3,317	3,464	3,292	2,715	3,350
Canada	3,216	3,266	3,124	3,128	2,991	2,772	2,731	2,897
Union of S. Africa[3]	389	480	459	519	509	578	650	620
Kenya[2]	27	36	—	51	58	—	70	84
Southern Rhodesia	12	12	11	13	10	8	8	9
Irish Republic	1,200	1,053	1,077	988	1,082	1,106	979	985
Foreign								
U.S.A.	10,001	19,022	15,187	13,661	15,170	14,875	12,963	12,911
Western Germany[1]	7,500	—	—	3,576	4,664	5,094	5,429	5,328
France	4,200[5]	2,520	2,175	3,346	3,307	4,429	5,413	4,921
Denmark	2,728	2,140	2,604	2,370	3,074	3,535	3,309	3,037
Sweden[1]	1,577	1,416	1,851	1,765	1,930	2,137	2,092	1,842
Netherlands	1,993	1,401	761	1,391	1,657	1,835	1,645	1,449
Italy	1,137	956	732	934	1,046	1,004	1,176	1,142
Argentina[1]	588	814	856	828	767	787	847	916
Finland	1,201	598	557	583	689	935	747	848
Belgium	1,476	898	1,000	1,220	1,299	1,385	1,424	1,415
Czechoslovakia	—	—	557	450	598	—	—	—
Austria	—	—	—	283	374	320	274	368
Brazil[1]	298	284	314	375	—	—	402	—
Switzerland	561	354	358	274	311	380	492	440
Norway[1]	286	221	81	175	211	227	221	203
Baltic countries[1]	1,298[4]	—	—	—	—	—	—	—

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[1] Factory or creamery production.

[2] Twelve months ending 30 June of following year.

[3] Twelve months ending 31 August of year stated. Farm production figures estimated for 1942, 1945 and 1948-50.

[4] Latvia—584,000 cwt.; Estonia—327,000 cwt.; Lithuania—387,000 cwt.

[5] Estimated.

TABLE WP VI

ESTIMATED PER CAPUT CONSUMPTION OF BUTTER

(lb.)

Country	1938	1942	1945	1948	1949	1950	1951	1952
Commonwealth								
United Kingdom .	24·1	7·7	8·5	12·5	13·8	16·8	14·6	10·9
New Zealand[1] . .	42·8	47·6	31·3	30·9	33·0	39·6	42·7	43·9
Canada	31·9	33·1	29·8	23·5	23·5	23·5	22·6	22·1
Australia[1] .. .	32·6	34·6	25·9	28·7	25·2	30·2	31·3	29·5
Southern Rhodesia[2] .	24·9	26·7	16·0	16·9	18·9	15·8	19·5	17·3
Union of S. Africa[3] .	—	5·1	5·0	5·8	5·3	6·3	—	—
Irish Republic . .	32·2	39·6	39·7	37·1	39·5	41·3	41·2	41·2
Foreign								
Sweden . . .	24·1	26·1	31·6	30·0	30·4	30·2	26·0	25·8
Belgium . . .	17·9[4]	12·1	14·3	24·9	24·5	23·6	23·1	24·9
Netherlands . .	12·3	17·4	8·4	11·9	6·4	6·0	6·2	5·5
Switzerland . .	15·0	9·3	10·3	10·6	12·8	13·2	13·2	13·4
U.S.A. . . .	16·4	15·7	10·8	10·2	10·6	10·8	9·5	8·7
France . . .	—	6·6	6·0	9·3	—	—	13·0	13·7
Denmark . . .	18·3	39·7	37·3	7·9	9·3	10·6	15·7	17·4
Argentina . . .	3·9	4·9	5·0	4·8	—	—	—	—
Italy	—	2·4	1·8	2·4	2·9	2·6	3·7	—
Western Germany .	19·4	—	—	9·1	11·3	13·2	13·9	14·3

[1] Twelve months ending 30 June of following year.

[2] Europeans only.

[3] Twelve months ending 31 August of year stated.

[4] 1937 figure.

TABLE WP VII

PRODUCTION OF CHEESE IN CERTAIN COUNTRIES

(thousand cwt.)

Country	1938	1942	1945	1948	1949	1950	1951	1952
Commonwealth								
United Kingdom .	860	400	400	530	600	1,100	878	1,102
New Zealand[1] . .	1,705	2,057	1,891	1,988	2,108	2,168	1,914	2,152
Canada . . .	1,134	1,889	1,723	887	1,137	973	927	734
Australia[1] . .	586	723	825	864	897	891	809	936
Union of S. Africa[2] .	113	146	149	177	164	159	196	191
Irish Republic . .	40	58	58	57	66	64	49	52

[1] Twelve months ending 30 June of following year.

[2] Twelve months ending 31 August. Farm production figures estimated 1942 and 1945.

TABLE WP VII—(*contd.*)

PRODUCTION OF CHEESE IN CERTAIN COUNTRIES

(thousand cwt.)

Country	1938	1942	1945	1948	1949	1950	1951	1952
Foreign								
U.S.A. [3]	6,476	9,931	9,971	9,772	10,714	10,463	10,365	10,672
Italy	5,065	4,187	3,203	4,163	4,663	4,921[5]	5,651	6,112
France	3,725	2,323	1,466	2,839	3,937	4,527	5,118	5,610
Argentina	840	1,144	1,592	1,752	1,948	1,890	1,663	2,114
Netherlands	2,476	1,015	735	1,906	2,521	2,500	2,761	2,812
Denmark	703	644[7]	862[7]	1,116	1,212	1,158	1,524	1,697
Sweden [4]	719	295	750	1,018	1,290	1,014	1,072	1,181
Switzerland	1,035	870	850	990	1,059	1,108	1,006	1,102
Czechoslovakia	525[6]	—	755	464	—	—	—	—
Norway	367	192	76	274	419	502	577	608
Finland [4]	217	79	84	138	197	266	319	358
Western Germany [4]	1,264	—	—	1,877	2,941	2,676	2,995	3,038
Austria	—	—	—	79	144	184	175	208
Brazil [4]	—	316	361	369	—	—	436	—
Belgium	—	—	93	98	149	184	233	284

[3] Excluding full skim and cottage cheese, which averaged 1,776,000 cwt. between 1938 and 1945.

[4] Factory production only. [5] Estimated. [6] 1937 figure.

[7] Dairy years ending 30 September.

TABLE WP VIII

ESTIMATED PER CAPUT CONSUMPTION OF CHEESE

(lb.)

Country	1938	1942	1945	1948	1949	1950	1951	1952
Commonwealth								
United Kingdom	8·9	14·0	9·7	8·4	9·8	10·1	10·5	7·7
Australia [1]	4·3	5·9	5·9	5·1	6·2	6·9	5·9	6·0
Canada	3·6	3·9	5·1	4·0	4·6	4·6	5·7	5·9
New Zealand [1]	4·5	5·1	6·0	6·4	6·0	5·8	5·7	6·1
Irish Republic	0·8	2·1	2·2	1·4	1·5	2·1	1·6	1·2
Foreign								
Switzerland	17·0	22·3	20·9	20·7	19·0	18·5	15·9	17·2
Denmark	14·1	12·8	20·7	18·5	14·1	11·5	14·1	12·6
Netherlands	17·0	11·2	9·7	12·1	14·6	11·0	12·6	13·0
Italy	—	10·1	7·9	9·9	11·0	11·4	13·4	—
France	—	7·3	4·9	9·5	—	—	14·1	14·6
Argentina	6·2	8·7	11·0	10·4	—	—	—	—
U.S.A. [2]	5·8	6·3	5·9	7·7	7·2	7·5	7·2	7·7
Western Germany	8·4	—	—	—	7·6	7·9	8·6	—
Belgium	—	—	1·4	8·6	9·2	10·1	11·3	11·7
Sweden	12·8	5·1	12·5	16·5	16·5	17·9	17·9	18·3

[1] Twelve months ending 30 June of following year.

[2] Excluding full skim and cottage cheese.

TABLE WP IX

Production of Condensed and Evaporated Milk in Certain Countries

(thousand cwt.)

	1938	1942	1945	1948	1949	1950	1951	1952
United Kingdom								
Condensed milk								
Whole								
Sweetened .	1,860 [1]	580	380	362	392	812	568	628
Unsweetened	800 [1]	800	920	986	1,164	1,424	884	1,380
Skimmed .	1,240 [1]	540	584	480	594	622	266	270
Canada								
Condensed milk								
Whole . .	82	206	255	313	210	130	168	154
Skimmed .	41	48	32	44	38	39	41	42
Evaporated milk								
Whole .	952	1,673	1,790	2,233	2,065	2,293	2,620	2,709
Skimmed			21	56	92	111	98	100
Australia [2]								
Condensed milk .	310	772	860	955	998	962	1,045	1,110
Concentrated milk [3]	33	170	183	264	265	293	305	261
New Zealand [2]								
Condensed milk [4]	142	250	320	460	478	—	494	564
U.S.A.								
Condensed milk								
Whole . .	800	1,231	1,967	1,534	1,330	982	912	973
Skimmed . .	1,493	2,060	4,638	2,140	1,948	1,967	1,886	1,460
Evaporated milk								
Whole . .	19,936	32,539	34,868	31,994	26,409	27,879	27,915	27,295
Skimmed .	2,055	2,843	4,058	4,411	4,784	4,911	4,417	4,361
Condensed or evaporated buttermilk	799	1,518	1,433	1,526	1,593	—	1,559	—
Netherlands								
Condensed milk								
Whole . .	1,741	—	—	1,224	2,112	3,109	2,166	2,374
Skimmed .	1,340	8	—	1	218	280	336	425
Denmark								
Condensed milk								
Whole . .	194	165	12	365	368	—	497	588
Skimmed .	142	31	96	144	352	—	114	118
France								
Condensed milk								
Sweetened .	302	—	162	322	—	—	1,457 [5]	1,213
Unsweetened .	186	—	60	155	—	—		
Argentina								
Condensed milk .	24	59	97	128	—	—	—	—
Japan								
Condensed milk	395	256	48	89	187	303	408	536
Switzerland								
Condensed milk .	138	114	110	69	65	77	67	77

[1] 1935-39 average.

[2] Twelve months ending 30 June of following year.

[3] For ice cream manufacture.

[4] Includes whole milk powder.

[5] Includes milk powder and baby foods.

TABLE WP X

PRODUCTION OF MILK POWDER IN CERTAIN COUNTRIES

(thousand cwt.)

	1938	1942	1945	1948	1949	1950	1951	1952
United Kingdom								
Whole . . .	180[1]	200	500	628	402	456	408	386
Skimmed . .	260[1]	80	74	126	186	354	80	128
Australia[2]								
Whole . .	225	358	346	395	441	369	332	436
Skimmed .			43	122	167	118	209	303
Buttermilk and whey			33	60	54	59	56	80
New Zealand[2]								
Skimmed .	156	172	176	332	404	528	636	772
Buttermilk .			10	34	80	144	143	108
Sugar of milk .			22	58	62	—	—	—
Canada								
Whole . . .	59	99	133	158	117	147	156	143
Skimmed . .	255	266	331	574	574	473	471	767
U.S.A.								
Whole . . .	192	555	1940	1519	1121	1150	1170	880
Skimmed . .	4012	5594	5893	6202	8526	7722	6400	7666
Buttermilk . .	571	622	443	374	441	401	407	461
Whey . . .	423	1111	1214	1118	1419	—	1250	—
Sweden								
Whole . . .	—	21	139	142	217	108	99	169
Skimmed . .	—	4	15	77	78	70	60	81
Argentina . . .	29	45	99	126	—	—	—	—
Netherlands								
Whole . . .	285	—	27	104	262	272	390	619
Skimmed . .	271	363	24	377	296	541	284	354
Denmark								
Whole . .	21	62	21	65	113	—	151	209
Skimmed .			71	69	69	—	53	61
Switzerland								
Whole . . .	24	43	41	61	79	71	77	77
Skimmed . .	65	20	47	30	39	47	49	55
Japan . . .	33	102	54	100	179	201	240	175
France . . .	82	—	40	37	—	—	—	—

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[1] 1935-39 average.

[2] Twelve months ending 30 June of following year.

TABLE WP XI

PRODUCTION OF CASEIN IN CERTAIN COUNTRIES

(thousand cwt.)

Country	1938	1942	1945	1948	1949	1950	1951	1952
Australia [1]	45	42	31	67	75	79 [4]	78	56
Canada	13	29	33	44	32	38	60	25
New Zealand [1]	37	20	24	108	106	132	190	142
Argentina	329	513	574	539	496	508 [5]	557	574
U.S.A.	433	377	110	128	164	171	193	—
Denmark [2]	18	15	22	106	45	—	—	—
Norway	63	7	6	41	65	63	95	89
Netherlands	47	61	—	7	12	38	91	10
Germany	112 [3]	—	—	—	—	—	26 [6]	9
France	325	104	31	66	—	—	335	—
Switzerland	10	22	18	16	8	20	43	18

[1] Twelve months ending 30 June of following year.

[2] Twelve months ending 31 March of following year, except in 1938 and 1942, when calendar year figures are given.

[3] 1937 figure.

[4] Production in butter factories only; comparable 1949-50 figure was 64,000 cwt.

[5] January-November.

[6] July-December.

TABLE WP XII

PRODUCTION OF MARGARINE IN CERTAIN COUNTRIES

(thousand cwt.)

Country	1938	1942	1945	1948	1949	1950	1951	1952
United Kingdom	4160	8120	8120	7990	8403	7478	8923	8892
Australia [1]	343	512	478	586	618	445 [5]	636	590
Canada	—	—	—	—	660	840	939	943
Union of S. Africa [2]	—	—	—	37	102	93	91	91
U.S.A.	3440	3801	5476	8106	7680	8364	9256	11482
Netherlands [3]	1405	323	728	2114	2884	3464	3445	3770
Norway [3]	1083	497	521	1222	1261	1328	1404	1541
Belgium	1255	225	1167	1373	1349	1282	1364	1450
Sweden	1202	799	963	998	1377	1627	1691	1829
Denmark	1600	—	—	1003	1075	1202	1440	1510
Finland	276	34	110	348	—	309	351	281
Germany [4]	8793	—	—	—	4703	7174	8853	10053
France	690	583	652	1195	1107	—	—	—
Poland	—	—	—	274	373	379	—	—
Austria	197	—	—	37	63	185	309	344

[1] Twelve months ending 30 June of following year.

[2] Twelve months ending 31 August of year stated.

[3] Including butter added during processing.

[4] 1938 figure relates to all Germany, 1946 and 1947 figures to the Bizone, and 1949 and 1950 figures to Western Germany.

[5] July 1950-May 1951

TABLE WP XIII

Estimated Per Caput Consumption of Margarine

(lb.)

Country	1938	1942	1945	1948	1949	1950	1951	1952
United Kingdom	10·0	17·6	17·1	17·5	17·9	16·7	18·3	18·9
Norway .	41·2	18·5	21·1	40·6	41·9	44·8	49·4	52·2
Netherlands .	15·7	3·5	8·8	22·0	31·1	37·5	37·0	39·5
Sweden .	20·5	13·9	14·3	15·7	22 0	24·7	27·6	29·1
U.S.A. . .	2·9	2·7	4·0	6·1	5·7	6·1	6·5	7·7
Finland .	7·9	0·9	3·1	9·5	—	—	9·7	7·7
Denmark .	47·4	—	—	24·7	27·8	30·9	37·3	38·8
Germany [1] .	13·4	—	—	—	—	15·4	20·7	23·6
Belgium .	14·8	—	—	17·0	16·1	16·3	17·2	18·3

[1] 1938 figures relates to all Germany, and 1950 figure to Western Germany.

X

XANTHINE OXIDASE. An enzyme in milk catalysing the oxidation of xanthine and identical with the Schardinger enzyme. *See* Enzymes.

XANTHOPHYLL. A yellow-red pigment of the carotene type which occurs to a small extent in milk.

Y

“ YARDSTICK.” For bacteriological tests. *See* Bacteriological grading ; Quality payment.

YEASTS. Yeasts are not of great importance in dairying but are usually responsible for yeasty and fruity flavours in milk, cheese, and butter, and they can cause “ blowing ” in tins of condensed milk.

The term *yeasts* includes the sporing or true yeasts (*Ascomycetes*) and the non-sporing (asporogenous) yeasts, sometimes called *torulæ*. *See* Cheese, p. 109 ; Condensed milk ; Flavours ; Media ; Stability.

Refs. : Lodder and Kreger-Van Rij (1952), *The Yeasts*, Amsterdam; Lindegren (1949), *The Yeast Cell, its Genetics and Cytology* ; Skinner (1947), *BR*, **11**, 227 (yeast-like fungi) ; Wilharm (1947), *M*, **2**, 382 (lactose-fermenting).

YEAST AND MOULD COUNTS. *See* Media.

YELLOW DYES. Dyes of the aniline yellow type were formerly used for colouring milk, etc.

“ YELLOW SPOT ” ON MILK BOTTLES. The characteristic “ yellow spots ” on badly-washed milk bottles are usually practically pure cultures of *Sarcina lutea*, a highly resistant coccus which can infect bottle-washing machines and especially the brushes on the older types. *See* Bottle washing ; Cleaning and sterilising ; Detergents ; Unclean flavour.

YIELD OF MILK. *See* Breeding ; Composition, factors affecting ; Feeding ; Management of dairy cattle ; Milk secretion.

YMER. A soured-milk drink which is replacing Yoghurt in Denmark. Skim milk is soured by an ordinary starter and concentration effected by separation of the curd. After addition of cream the milk is homogenised and filled into bottles at about 3° C. The bottles are held in ice until the culture is consumed.

YOGHURT. Yoghurt is a term used in a general sense for any commercial culture of high-acid lactic acid rods, but strictly it is only applicable to cultures of *L. bulgaricus* and other lactic organisms.

Milk for Yoghurt making should be homogenised and heated to 90° C. flash or to 70° C. for ½ hr., cooled to 40°–42° C. and inoculated at this temperature with about ½ per cent. of a freshly-grown culture of *L. bulgaricus* and *Str. thermophilus* grown together. The mixture should be immediately filled into bottles and incubated in air or water baths at 40° C. for about 2½ hr. until clotting takes place. When the milk is firm the bottles are removed and cooled to 5°-10° C. They should be held at this temperature until the Yoghurt is consumed. The rigidity of Yoghurt may be increased by concentrating the milk or adding stiffening materials such as alginate or gelatine. Yoghurt is considered to repress putrefaction in the bowel. *See* Acidophilus milk ; Lactic acid bacteria.

Refs. : Burke ; Orla-Jensen ; Orla-Jensen (LAB) ; Davis (1952), *F*, **21**, 249, 284; Pette and Kooy (1952), *NMDJ* **6**, 233 (phage).

Z

ZEBRA. *See* Mammals.

ZINC. Zinc-covered or galvanised pails are still in use, particularly on dairy farms but their use should be discontinued as they are difficult to clean from the bacterial point of view.

ZINC CHLORIDE. A solution of zinc chloride can be used to prevent mould growth on wooden shelves.

ADDENDUM

TABLE NVF I—NUTRITIVE VALUE OF COMMON FOODS

(*All figures per* 100 *g. or* 100 *ml.*)

	Calories	*Protein* (*g.*)	*Fat* (*g.*)	*Carbohydrate* (*g.*)	*Calcium* (*mg.*)	*Iron* (*mg.*)	*Phosphorus* (*mg.*)
eam cheese . .	813	3·2	86	tr.	29·6	0·14	44
con	509	12·5	49·3	0	13·5	0·9	94
lton cheese . .	475	25·1	40	tr.	362	0·46	304
eddar cheese . .	423	25·0	33	tr.	810	0·57	545
ast beef . . .	385	21·3	32·1	0	5·8	4·6	237
rrant bun . .	298	8·1	7·6	54·5	35·9	2·13	65
ney . . .	288	0·4	tr.	76·4	5·3	0·39	17
er (fried) . . .	262	29·0	14·5	2·4	8·8	21·7	576
ite bread . .	241	7·9	0·7	53·7	23·1	1·0	73
rring . . .	235	21·8	15·1	1·5	38·6	1·9	339
rned beef . . .	231	22·3	15	0	12·8	9·8	119
Eggs	163	11·9	12·3	0	56	2·53	218
b nuts (whole) . .	143	3·2	13	2·4	16	0·38	82
ans (baked) . .	93	6·0	0·4	17·3	61·6	2·05	184
tato (old raw) . .	87	2·1	tr.	20·8	7·7	0·75	40.3
ole Milk . . .	66	3·3	3·7	4·8	120	0·08	95
(pale draught) .	55	0·3	tr.	3·2	10·9	0·05	21·5
ple (whole) . .	36	0·2	tr.	9·3	2·8	0·23	6·7
ange (whole) . .	27	0·6	tr.	6·4	31	0·25	17·8

Data from *Chemical Composition of Foods*, McCance and Widdowson, 1942, H.M.S.O.

ADDENDUM

GRASS TETANY. The term " Grass Tetany " is frequently used to designate a disorder of dairy cows which may occur a week or so after the cows are first admitted to grass in springtime. The complaint is widely known in New Zealand and in The Netherlands but seldom occurred in Great Britain until recent years, a change of incidence which coincided with marked improvements in the grassland management of the country.

The first symptoms of illness to be noticed are usually a staggering gait or unco-ordinated movement, nervous twitching followed by collapse and convulsive tetany; unless suitable veterinary treatment is administered quickly the animal will probably die, but spectacular improvements usually follow the injection of a solution of magnesium sulphate or even of the mineral solution normally injected in the treatment of milk fever. A characteristic feature of the condition is that blood analysis reveals a very low concentration of magnesium in the blood and consequently veterinarians usually name the disorder " hypomagnesaemia ". The exact physiological cause of the disorder is still unknown, but it probably starts as a digestive disturbance followed by dysfunction of certain organs and abnormal metabolic processes.

Pastures which have been heavily fertilised with sulphate of ammonia or liquid manure are more liable to induce grass tetany than less productive pastures. The danger of the disorder can, however, be reduced or eliminated by attention to the following items of management: by ensuring that when cows are turned out to grass after a winter period of stall feeding, the change is gradual rather than abrupt, and that during the first few weeks of grazing the grass diet is supplemented with a few pounds of hay or low protein concentrated foods such as oats, barley or maize. A sward composed entirely of grass appears to be more " tetany prone " than clovery swards, and if there is good reason to suspect a pasture of being dangerous, the cows may derive benefit from a daily dose of of about 2 oz. of magnesium oxide (or calcined magnesite) given in the concentrate mixture or as a daily drench.

Although milking cows appear to be highly susceptible to this disorder, a very similar complaint sometimes occurs in other classes of cattle both in the spring time and at other seasons of the year.

Refs.: S. Bartlett, B. B. Brown, A. S. Foot and S. J. Rowland ; Ruth Allcroft and W. H. Parr (1954), *BVJ*, **110,** 3-19.

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